School Science and Mathematics

Vol. XIX, No. 1 | January, 1919 | Whole No. 156

TRANSPIRATION AS ENERGY DISPERSAL.

By Charles A. Shull,

University of Kentucky, Lexington.

One of the subjects which receives considerable attention in our elementary textbooks of botany, but which continues to be presented in a manner more or less unsatisfactory from both the pedagogic and scientific point of view, is transpiration. While transpiration has received a large amount of attention in recent years, and while much valuable progress has been made in measuring and interpreting transpiration, this progress has not been sufficiently reflected in recent texts. In particular, the paragraphs which attempt to consider the significance of transpiration to the plant's own life are most unsatisfactory. And at the close of the discussion the important question as to why the plant transpires such a very large amount of water during the growing season has been left without an adequate answer.

Unfortunately, some of the best contributions to our knowledge of the meaning of transpiration to the plant itself have been published in magazines not generally available to secondary school men. This is true especially of the contributions of investigators whose work has appeared in foreign journals of far too limited circulation in America. The purpose of this discussion is to present a few of the salient facts which others have discovered, and to shift the emphasis from the material changes of the process of water loss to the energy changes involved.

One of the ways in which transpiration is frequently presented is that it is the unavoidable consequence of the need for the gases, oxygen and carbon dioxide, in two of the major processes of plant life. In leaving passageways for ingress and egress of gases which must dissolve in wet cell walls, the conditions leading to water loss were unavoidably produced. We all recognize the unavoidableness of transpiration so long as vapor pressure in the plant is higher than the vapor pressure of the surrounding

air, and so long as water-permeable membranes exist. Moreover, this thing which cannot be avoided may even become dangerous at rare intervals when the life of the organism is threatened by transpiration proceeding more rapidly than root absorption can make good the water loss. But this presentation does not begin to reach the heart of the matter.

Another method of handling the subject is to point out the advantages accruing to the plant by virtue of its transpiratory process. One of the chief advantages pointed out is that the plant secures very rapid transportation and distribution of mineral nutrients needed for the growth of all living protoplasm. And it is true that the mass movement of solutes in the tracheae, which is the result of transpiration occurring at the upper end of the peculiarly constructed conducting system of plants, is a great advantage, particularly to tall plants. For if the salts needed by tall plants were obtainable only as a result of diffusion migration, there would probably be no tall plants. The migration of salts, even when the diffusion gradient is high, is very slow. For instance, as Haskell indicates, it would require six weeks for a molecule of barium nitrate to travel thirty centimeters by diffusion, with a concentration gradient running from saturation to zero in that distance. The length of time necessary for any given molecule to traverse the stem of a tree fifty meters tall by diffusion would require many years, for the concentration gradient for the soil minerals is quite low. It might conceivably require a century to make the same journey by diffusion that is accomplished in a few days by mass movement.

Another advantage sometimes suggested is the concentration of the salts in the leaves, as though the salts would be too dilute and inadequate for the plant unless transpiration were carried on with great rapidity. This view is entirely untenable, however, for it involves the false assumption that the more water which passes through the plant, the more salts the plant obtains from the soil solution. Experiments have shown that when plants are grown in sunshine, where transpiration is most rapid, they take in less salts than when grown in the shade, where transpiration is relatively much slower. The work of Hasselbring on Cuban tobacco and of Burns on white pine seedlings shows that the absorption of salts and water are independent processes and that water intake can be increased without accelerating the absorption of salts.

There is still another view of transpiration which regards it as a necessary process, so necessary that, if it were completely prevented on a bright warm day, it would be as serious to the plant as would deprivation of oxygen to a human being. And this view ascribes to it as its chief rôle the dissipation of energy. Some of the facts upon which this view rests are so valuable that every teacher of botany in secondary schools should be in possession of them. Disregarding the slight energy changes involved in condensation and digestion of foods, there are at least three ways in which energy may be accumulated in the plant: (a) the absorption of radiant energy; (b) respiration; (c) intake of energy from the atmosphere if the latter happens to be warmer than the plant.[1] There are also three ways in which the energy may be dissipated; (a) photosynthesis, which utilizes a small amount of the absorbed radiant energy; (b) dissipation into the atmosphere if the latter is cooler than the plant; and (c) evaporation of water, or transpiration.

These processes are all interrelated and the energy changes occurring at any given moment are somewhat complex. But for the purposes of this discussion we can leave aside the changes due to photosynthesis, which uses less than one per cent of the energy received from the sun, and to respiration, and thermal emissivity. These changes are all small under ordinary circumstances, although thermal emissivity may become important in special plants or under exceptional conditions, as in succulents in desert regions. The very large source of energy is of course the absorption of radiation from the sun, and most of this energy is dispersed by the evaporation of water.

In order to show that energy dispersal is vitally necessary, we must know the amount of energy absorbed per unit area per unit time, and the quantitative effects of the absorption if it were not dissipated. By means of a radiometer it has been found that about .8 calorie of energy falls upon a square centimeter of leaf surface in one minute during direct bright insolation. Of course, the amount will vary with atmospheric and seasonal changes. Not all of this energy is absorbed by the leaf. Part of the incident energy is reflected, and some of it passes on through the leaf. About 25 per cent of it passes through, but unfortunately we do not know how much light is reflected from the leaf surface. It would seem certain, how-

[1]Intake and outgo of energy from one body to another due to conduction, convection, and radiation, is known as thermal emissivity.

ever, that the reflection is not negligible, since even a dead black surface will reflect perhaps one per cent of the light falling upon it. If we assume that reflection from the leaf is 10 per cent, then the energy absorbed would be 65 per cent of the total incident energy. The total absorption would then be .52 calorie per square centimeter per minute. At this rate enough energy is received by a square meter of leaf surface in one hour to evaporate more than half a liter of water. Therefore, the reason why the plant transpires so much water during the growing season is because it receives so large a supply of energy.

What would happen if this energy were not dispersed? If the energy intake could go on without any utilization for photosynthesis, without loss by thermal emissivity, and without evaporation of water, it would accumulate in the leaf as heat energy, and rapidly raise the temperature of the leaf. Just how rapidly would the rise in temperature proceed? A calorie is the amount of energy required to raise the temperature of one gram of water one degree from zero; and we can calculate the rate of rise which the leaf would undergo if we know the amount of energy received per unit time and the mass and specific heat of a square centimeter of leaf substance.

The mass of a square centimeter of leaf substance will vary from plant to plant, or from leaf to leaf, or in various parts of the same leaf. But in some cases a square centimeter of leaf substance weighs about .02 gram. The specific heat of the fresh leaf substance is high, since it is largely composed of water, and has been given as .879 as compared to water = 1[2].

The rate of rise in temperature of the leaf per minute can be computed by dividing the energy absorbed per minute by the mass times specific heat. In the form of an equation, $\frac{R \,.\, a}{m \,.\, s}$ = rate of rise in degrees per minute. In this equation R is the total radiant energy falling upon the unit leaf surface per unit time; a is the coefficient of absorption; m is the mass of the leaf unit, and s its specific heat. Substituting the given values of these quantities, we have $.52 \div .01758 = 29.6°$. The leaf is receiving energy fast enough to raise its own temperature almost 30° per minute. And since the leaf usually has an initial

[2]The figures used in part, and the discussion, are based on "Researches on Some of the Physiological Processes of Green Leaves," Brown, H. T., and Escombe, F., Proc. Roy. Soc., Lond. B., 76:29-111, 1905.

temperature of 25° to 30° C., we see that it would approach 60° C. in a minute if no energy dispersal occurred. In other words, plants would reach the death temperature of their protoplasm in a minute or less if it were not for the constant dissipation of the radiant energy, the chief means of which is transpiration. There is no doubt that transpiration is vitally necessary, and that its chief function is energy dispersal.

Another problem connected with transpiration which is always handled in an unsatisfactory manner in elementary textbooks is the problem of stomatal movement. Most frequently stomata are represented as regulating to a certain degree the water loss, and this they no doubt do accomplish to a certain extent. But the main difficulty is that we have not thought sufficiently of water loss as energy dispersal. Instead of regulating water loss, they are regulating energy loss, the water evaporated merely measuring the quantity of energy. It is now generally recognized that stomata are usually open by day and at least partially closed at night in the majority of plants. Any student can convince himself of this fact by using the little porometer devised several years ago by Darwin and Pertz for such studies.

This diurnal movement of stomata is by far the most significant movement they have, and the mechanism by which they open and close has been described by Iljin. According to his account, when the sun goes down at night, or whenever the radiant energy is cut off artificially, certain soluble carbohydrates in the cell sap of the guard cells are condensed into insoluble form, and the osmotic pressure of the guard cells falls greatly. They lose part of their water to surrounding cells and are soon nearly closed. The following morning, or when light is renewed, the radiant energy reverses the condensation of the carbohydrates, the osmotic pressure is rapidly increased in the sap of the guard cells, they take in water from contiguous cells, and are soon wide open. The stomata open wide at the time energy receipt begins, and have energy dispersal as their chief function. At night, when energy receipt from the sun is at a minimum and when transpiration is mostly due to intake of energy by thermal emissivity, stomata may well be closed. Stomatal movement becomes most intelligible when thus linked up directly with the current of energy flowing through the plant. Of course, if transpiration goes on more rapidly than root absorption of water can supply the needs of the leaf, guard cells as well as other cells may lose their turgidity and collapse, thus

partially closing the stomata. But this is not to prevent water loss. It is too late for that. It is to be looked upon rather as a temporary breakdown of the thermoregulative mechanism.

It is well known that a saturation deficit or incipient drying occurs in the leaf without bringing about the closure of stomata. If energy receipt continues while stomata partially close, or during incipient drying to such a degree as to decrease normal energy loss, then the temperature of the leaf must rise above that of the surrounding atmosphere, and thermal emissivity will supplement the ordinary means of energy dispersal.

There are some plants whose stomata do not close at night. This does not mean necessarily that such plants will transpire more than if the stomata were closed. No more water will be evaporated than the energy received can vaporize. If conditions of relative humidity should lead to more rapid evaporation than sunlight energy makes possible, the leaf becomes cooler than the atmosphere and receives additional energy by thermal emissivity. The same would be true for plants with stomata open at night. Of one thing we can be quite certain, that the total energy received by the leaf from all sources and the total utilization of energy are on the average equal quantities, and it is very easy to determine what must happen in the leaf as the conditions affecting intake and outgo of energy are changed.

Such a treatment of transpiration and stomatal movement puts the emphasis where it belongs, on the energy changes involved rather than upon the material changes. It has proved to be a satisfying presentation of the subject to large numbers of students in college classes, and there is nothing in it too difficult for students in secondary schools if the instructor himself has a clear conception of the processes.

BULLETIN ON THE TRAINING OF TEACHERS OF MATHEMATICS FOR SECONDARY SCHOOLS.

There has just been issued by the Bureau of Education at Washington a Bulletin on "The Training of Teachers of Mathematics for Secondary Schools of the Countries Represented in the International Commission on the Teaching of Mathematics." This Bulletin has been prepared by Professor R. C. Archibald of Brown University. It is a work of nearly three hundred pages, giving in great detail the requirements set by the various governments for a teacher of secondary mathematics. The Bureau of Education has a limited number of copies of this Bulletin which it can send to those who are particularly interested in the work. After this limited number has been exhausted, copies can be obtained from the Superintendent of Documents, Government Printing Office at Washington, D. C., at thirty cents per copy.

THE FIELD EXCURSION IN HIGH SCHOOL BIOLOGICAL COURSES.

BY H. J. VAN CLEAVE,
Zoological Laboratory, University of Illinois.

It is a common impression that field excursions in high school biological courses are rarely successful as a method of instruction. This impression is reflected both by the reaction of the students and by the confession of many teachers. In the average high school a field trip is regarded by the students as a picnic, while the teacher frequently returns with the feeling that little has been accomplished. In spite of these facts, many feel certain that the field excursion should hold an important place in the high school biological courses.

As teachers we have long been accustomed to assign a definite grade to all of the material evidences of accomplishment of our students. In consequence, we are apt to forget that some of the things which may have the greatest influence in affecting the whole outlook and future of our students are the intangible, immeasurable attainments which accompany or constitute an education. We therefore frequently question the value of a means of instruction, not by what it conveys to the pupil but upon the basis of the direct obvious result. In this light field study frequently shows to very poor advantage. It is true that field excursions offer a means of acquainting the individual with the living objects of his environment in a much more direct and practical manner than does ordinary routine of laboratory study. Why, then, should this element in the teaching of the biological sciences be so unsatisfactorily developed? As a rule, a few difficulties are responsible for the unsatisfactory results of field exercises. An analysis of these difficulties may be of value to those who have discarded this method of instruction as unprofitable and may at the same time offer a means of successful organization for teachers who have never carried on this type of work.

We frequently hear science teachers speak of the necessity of acquainting the child with his environment. What does this mean and what is the necessity of emphasizing it? No individual may escape from his environment, therefore why does not he of himself become acquainted with the objects found in it? Our educational system as a whole is frequently described as one which emphasizes powers of memory and of conforming the mind to the opinions of others. Little emphasis is placed up-

on the necessity for direct and correct observations. As a result, the older one gets the more inclined is he to take for granted the things about him without raising any question as to relationships or causes. He is soon discouraged in the endless quest for reasons and explanations which are so characteristic of the small child. Such an attitude is entirely contrary to the whole spirit of science. Therefore, in preparing the student's mind to grasp the truths of nature it becomes necessary to teach him how to observe and how to seek explanation for the commonest things about him. It remains for the sciences to introduce the individual to his most familiar surroundings before he may become really acquainted with them.

The trouble with most of our teaching is the fact that we take too much for granted. Facts which become so obvious to us through frequent meeting of them may require extended explanation to the beginning student in the high school. The fault with many of our field excursions is the fact that the students are brought into their natural environment but the teacher forgets to give them an introduction to the things found there. Such a field trip differs very little from the ordinary vacation experiences of the students, especially of those who live or have lived in the country. As individuals they hunt snakes, watch grasshoppers "spit tobacco," and catch frogs; in fact, the very things they would naturally do if turned loose under any other circumstances. The teacher has no plan for the trip; there is no object upon which to focus the attention. As a net result of the trip each student has probably become familiar with some few additional facts of direct interest to him but he could not in any sense be considered as having become acquainted with his environment. Still it might be contended that he had ample opportunity afforded him. His opportunities of learning were about equal to those of a small child locked alone in a vast library—great stores of knowledge all around with no one to teach him how to appropriate it for his own use.

If we wish to have a student become acquainted with facts from a textbook, a definite, limited assignment is made. Yet the teacher who prides himself upon the definiteness and reasonableness of his text assignments is often among those who are guilty of wasting time and opportunity by conducting indefinite, aimless field excursions.

Definiteness of object must be considered as one of the things most essential for the success of a field excursion. Field study

must be planned and outlined just as definitely and as minutely as the most difficult laboratory exercise. The teacher must be thoroughly acquainted with the materials which he intends to present to the class. A few well-organized new facts or new relations or even a few new interpretations are worth far more to the individual student as a means of acquainting him with his environment than a mass of unrelated observations. In order to insure careful study which would lead to the discovery of facts beyond what the student has found in his own independent observations of his surroundings, the excursion must not only have a definite object but in addition that object must be distinctly limited. "Relations of animals to vegetation" constitutes an object for field study, definite, to be sure, but too broad and scattering for effective work in any one trip. This same heading would furnish abundant material for numerous field trips, each in itself restricted to some definite phase of the general problem. "Insects as carriers of pollen," "Insects affecting the apple," "Insects affecting the corn," "Birds as carriers of seeds," "Mammals as carriers of seeds," are all restricted phases of the general topic mentioned above. In scope, each of them is capable of producing definite results, both in the accumulation of new facts and in leading the student to an appreciation of the correlations of the most common living objects of his surroundings.

Definiteness of object and limitation of it need not entirely preclude the possibility of calling attention to unrelated things of uncommon occurrence or of especial interest. To contend for too strict an application to one object in pursuing field work would be placing oneself in the same category with the over-specialized sportsman who refused to shoot a hare because he was clothed in his partridge hunting suit.

Pursuit of a definite limited object in turn aids in solving the problem of discipline which is frequently not attempted in a "general" trip. Definite, tangible results, either in the form of collections made by each individual or in that of a written report, serve to enlist the interest of each individual for the work and thereby diminish the risk of play crowding out the real object of the exercise. If the field excursion is thoroughly organized and clearly outlined, discipline should be no greater task in the field than in the classroom or laboratory.

The difficulties involved in field study in the biological sciences are on the whole those growing out of the improper organization of this phase of the work. Field excursions outlined and or-

ganized with thoroughness constitute a means of instruction with peculiar opportunity for awakening within the mind of the student an understanding and an appreciation of the correlations which exist between the unrelated observations and experiences of his everyday life and the isolated facts gained by the ordinary laboratory procedure.

SAVE TO KEEP THE WAR WON.

American marines and soldiers held for three mortal days on the Marne at Chateau Thierry against the picked troops of the German army. Did they quit the moment the Germans turned back and tried to find a place to dig in? No, they did not. They went right on fighting the German rear guard. They drove them until the retreat turned nto a desperate rout. And they kept right on chasing them, first at one point and then at another, until they had cleaned them out of the valley of the Meuse and the forest of Argonne, and the town of Sedan. Then came the German surrender—the most abject and crushing fall in all the annals of warfare.

In plain language, the American troops operated on the good American rules of the game: "Keep your eye on the ball. Follow through. Play the game right and play it to the finish." Of course, they won. They couldn't lose, playing the tragic game of war that way.

Now there is a parallel calling for the same method of play.

The American Expeditionary Forces went abroad to fight, to be wounded, to be killed, if necessary—fully determined to carry out their pledge of victory.

What was the direct pledge of the American people to those men? The contract was not all on the shoulders of the troops. The nation had to take one side of the contract. The American people assumed the solemn obligation to back up the fighters with money, arms, supplies, medical, moral, and social maintenance.

The Army in France took a contract to fight.

The Army at home took a contract to pay the bills.

The fighting Americans have made good on their contract.

Now it is up to the people at home to pay the bills.

That is why the Treasury is selling Anticipation Certificates covering next year's federal taxes and discounting the subscriptions to the coming Fifth Loan. All the money raised on the previous four Liberty Loans has been spent and the bills have not been paid.

Nearly all the American soldiers are overseas and it will cost many hundred millions to bring them back. Meantime, they must be fed and kept up to the scratch in appearance, health, morals, spirits, and every other way.

There is only one way to do it. This paying business takes grit.

Every American must go right on saving as hard as before the armistice.

Save every nickel, every dime, quarter, and dollar that can be spared from living expenses. Put savings into the banks, or buy Thrift and War Savings Stamps.

Then when the time comes to subscribe for the Fifth Loan everybody will be ready to carry out the contracts we have on hand.

The soldiers won the peace by fighting.

We have the job of paying for the peace.

Save and prepare for the Fifth Loan.

BLAISE PASCAL'S NEW EXPERIMENTS ON VACUA.

Translated from the third volume of Pascal's works, Hachette.
1872, by Willard J. Fisher,
Worcester, Mass.

To the Reader.

My dear reader: Certain considerations hindering me from publishing at present a complete treatise, wherein I have reported a quantity of new experiments done by me on vacua, and the consequences which I have drawn from them, I have decided to give an account of the principal ones in this abstract, in which you will see in advance the plan of the whole work.

The occasion of these experiments is as follows: It is about four years since an experiment was tried in Italy thus: A glass tube about four feet long with one end open, the other hermetically sealed, being filled with quicksilver, then the opening closed with the finger or otherwise, and being placed perpendicular to the horizon with the stopped opening downward, is plunged two or three finger-breadths into some more quicksilver contained in a vessel filled half with quicksilver, half with water; if the opening be unstopped, remaining the while submerged in the quicksilver of the vessel, the quicksilver in the tube will descend partly, leaving in the upper end of the tube a space empty in appearance, the lower end of the same tube remaining full of the same quicksilver up to a certain height. And if the tube be raised a little, so that the opening, previously dipped into the quicksilver of the vessel, leaves the quicksilver and comes into the region of the water, the quicksilver in the tube ascends with the water to the top of the tube and the two liquids are mingled in the tube; but finally all the quicksilver falls, and the tube is altogether full of water.

This experiment having been reported from Rome to Rev. Fr. Mersenne, Minimite at Paris, he announced it in France in the year 1644, not without exciting the admiration of all savants and amateurs. As by their reports it became famous everywhere, I learned of it from M. Petit, superintendent of fortifications, a man well versed in *belles lettres*, who had heard of it from Rev. Fr. Mersenne himself. At Rouen, therefore, we did it together, this M. Petit and I, the same as had been done in Italy, and we found detail for detail what had been reported from that country, without then observing anything new.

Then, reflecting by myself on the consequences of that experiment, I confirmed myself in the idea wherein I had always

been, that a vacuum was not a thing impossible in nature, and that she did not avoid it with as much horror as many imagined. What forced me to this idea was the slight foundation which I saw for the maxim so (generally) received, that nature does not suffer a vacuum, which is based upon experiments for the most part entirely false, although held entirely reliable; and of the rest, some are far removed from contributing anything to the proof and show that nature abhors too great congestion, and not that it avoids a vacuum; and the most favorable prove nothing more than that nature has a horror of a vacuum, not that it cannot suffer one.

To the weakness of this as a principle, I would add the observations which we daily make about the rarefaction and condensation of the air which, as some have shown, can be condensed even to the thousandth part of the space formerly occupied by it, and expands so strongly; which I considered as necessarily so, either because there is much empty space between its parts, or because there is penetration of dimensions. But since the world as a whole did not accept this as proof, I believed that this Italian experiment was capable of convincing even those most biased as to the impossibility of a vacuum.

Nevertheless, the force of prejudice always finds objections which take away deserved credit. Some say that the top of the tube is full of the vapors of mercury; others talk of an imperceptible granulation of rarefied air; others, of a kind of matter which does not exist outside of their imagination; and all, conspiring to outlaw the vacuum, emulate one another in that faculty of the mind which they call subtlety in the schools, and which in the solution of real difficulties gives nothing but vain words without foundation. I therefore resolved to do experiments so convincing as to be proof against all possible objections; of such I made a great number at the beginning of this year, some of them related to the Italian experiment, others entirely unrelated and having nothing in common with it. They were so exact and so satisfactory that by their means I showed that a vessel as big as can be made can be rendered entirely empty of all the kinds of matter which fall under our senses, or which are known in nature; also, what force is necessary for producing a vacuum.

Moreover, I tested the height necessary for a siphon to produce the effect expected of it, above which limiting height it no longer acts, contrary to the opinion so universally held in the

world through so many centuries; also, the small force needed to draw the piston of a syringe without any matter taking its place; and many other things which you will see in the complete work, wherein I design to show the force employed by nature to avoid a vacuum, and how she actually allows and suffers it in a large space, which is easily made empty of all forms of matter which fall under the senses. Hence, I have divided the complete treatise into two parts, the first containing at length an account of all my experiments and a recapitulation of what they mean, divided in several maxims; the second, the consequences which I have deduced from them, in several propositions, wherein I have showed that the space apparently vacuous, as it appeared in the experiments, is in fact empty of all the forms of matter which fall under the senses or are known in nature. In the conclusion I give my ideas on the subject of vacuum, and reply to possible objections. So, I content myself with demonstrating the existence of a large vacuum and I leave it to savants and scientists to find out what happens in such a region; as, whether animals can live there; whether glass in it diminishes its refracting power; and everything one can do there; not mentioning this in the treatise, of which I have thought fit to give you this abstract in advance, since, having made these experiments at much expense and spent much trouble and time, I feared that somebody else who had not spent the time or the money or the pains, anticipating me, might give to the public facts of which he was not a witness, and so which he could not describe with the accuracy and the order necessary for proper deductions; no one having had tubes or siphons as long as mine, and few being willing to take the trouble to have them.

And since honorable people join to the general inclination of all men, to defend themselves in their just possessions, also that of refusing honor not due them, you will no doubt approve me likewise, defending myself against those who would wish to deprive me of any of the experiments which I here give you or promise you in the complete treatise, for they are my own invention; and against those who would attribute to me that Italian experiment just described, since it is not mine. Although I have done it in more ways than anyone else, with tubes twelve and even fifteen feet long, nevertheless I will not speak of that alone in this, not being its inventor, as I have no design of giving what is not my own, the fruit of my own ingenuity.

(*On this, see letter printed at end. W. J. F.*)

Abstract of the First Part, Wherein Are Described the Experiments.

Experiments.

I. A glass syringe with a well fitting piston is plunged entirely into water, and its opening is closed with the finger, so as to touch the piston at the bottom, for this purpose the hand and arm being put into the water; one has need of only a moderate force to withdraw the piston and separate it from the finger without the water entering in any way (something the philosophers have believed could not be done with any finite force); then the finger is felt to be strongly and painfully drawn in; the piston leaves a space empty in appearance, into which it does not seem that anything can have got, since it is completely surrounded with water that can have had no access, the opening being closed. If one draws the piston further out, the space empty in appearance becomes greater, but the finger feels no greater suction; and if one removes the syringe almost entirely from the water, so that only the opening remains immersed, with the finger closing it, then on removing the finger the water, contrary to its nature, rises with violence and entirely fills the space vacated by the piston.

II. A bellows thoroughly tight on all sides does the same thing with similar precautions taken, against the belief of the same philosophers.

III. A glass tube forty-six feet long, with one end open and the other hermetically sealed, filled with water, or, better, with red wine for better visibility, is then stopped and in that condition raised and placed perpendicular to the horizon with the stopped end down and immersed about a foot in a vessel full of water. If the opening is unstopped, the wine in the tube descends to a certain height, about thirty-two feet above the level of the water in the vessel, runs out and mixes with the water in the vessel, which it colors slightly, while it separates from the glass at the top, leaving a space about thirteen feet long, apparently empty, where it does not seem as if anything could have got in. If the tube be tipped, then the height of the wine in the tube decreases by the inclination, the wine ascends till it reaches the height of thirty-two feet; and if finally the tube be tipped just to the height of thirty-two feet, it is entirely filled, sucking in, moreover, the water which had been ejected by the wine; so that it is full of wine from the top to thirteen feet from the bottom, and full of water slightly tinted in the thirteen feet below.

IV. A siphon with unequal legs, the longer fifty feet, the shorter forty-five, is filled with water and the two openings stopped and placed in two vessels of water, each immersed about a foot, so that the siphon is perpendicular to the horizon, and the water surface in one vessel is about five feet higher than that in the other. If the two openings be unstopped with the siphon in this condition, the longer leg does not draw the water from the shorter, and consequently not from the vessel in which it is, contrary to the beliefs of all philosophers and artizans; but the water falls in the two legs standing in the two vessels to just the same height as in the tube just described, reckoning the height from the surface of the water in each vessel; but after inclining the siphon below the height of about thirty-one feet, the longer leg draws the water from the vessel of the shorter one; and on raising it above this height, this stops, and both the two sides discharge each into its own vessel; and on lowering, the water in the longer draws the water in the shorter as before.

V. If into a fifteen foot tube sealed at one end and filled with water there be put a fifteen foot cord with a thread attached to its end (this is to be inserted into the water slowly, so that it may take it up little by little; air might somehow be inclosed in it) so that there is nothing outside the tube except the thread attached to the cord for drawing it out, and if the opening be immersed in quicksilver, when the cord is withdrawn little by little, the quicksilver rises proportionally until the height of the quicksilver added to the fourteenth part of the height of the remaining water is two feet three inches; then, as the cord is pulled the water leaves the top of the tube and leaves a space empty in appearance, which continually increases as one keeps on pulling the cord. If the tube be inclined, the quicksilver of the vessel enters, so that with sufficient inclination the tube is entirely filled with quicksilver and water which strikes the top of the tube violently, making the same sort of a noise or report as if the tube were broken; and in fact, it does run a risk of breaking. To get rid of the little bit of air which, so to speak, is lodged in the cord, one can do the same experiment with a number of little wooden cylinders attached together with a brass wire.

VI. A syringe with a perfectly fitted piston is put into quicksilver so that its opening is immersed at least an inch and the rest of the syringe stands perpendicularly outside. If the piston be drawn still further, the syringe remaining as described, the quicksilver enters through the opening of the syringe, rises

and remains in contact with the piston until this has gone up in the syringe two feet three inches. Beyond this height, if the piston be drawn still further, it does not draw the quicksilver any higher, but this leaves the piston and remains constant at this height of two feet three inches; so that there is made a space empty in appearance, which becomes greater as the piston is drawn further. It is probable that the same thing happens in a suction pump, and that the water rises in this only to the height of thirty-one feet, which corresponds to two feet three inches of quicksilver. More remarkable is this, that the syringe, if weighed in this condition, without removing it from the quicksilver or moving it in any way, has the same weight, although the space apparently empty be as small as desired, as when, withdrawing the piston farther, we make this space as large as we choose, and that it always weighs the same as the body of the syringe together with the quicksilver contained at the height of two feet three inches with not any apparently empty space—that is, when the piston has not yet left the quicksilver in the syringe, but is at the point of breaking away from it, if it is pulled out ever so little. So that the apparently empty space, although all the bodies about it tend to fill it, causes no change in weight, and, whatever be the differences in size among such spaces, there is none among the weights.

VII. A siphon whose long arm is ten feet, short arm nine and a half, is filled with quicksilver and its two openings put into two vessels of quicksilver, each immersed about an inch, so that the quicksilver surface in one is about a half foot higher than that in the other. When the siphon is perpendicular, the long arm does not attract the quicksilver from the short; but the quicksilver, breaking at the top, descends in each arm and empties into the vessels and falls to the usual height of two feet three inches, measured from the surface of the quicksilver in each vessel. If the siphon be inclined, the quicksilver mounts again from the vessels into the tubes, fills them and commences to flow from the short arm into the long, and so empties its vessel. For this inclination of the tubes wherein is the apparent void, when they stand in any liquid, always draws the liquids from the vessels if the openings of the tubes are not closed, or draws the finger if it closes the openings.

VIII. The same siphon is completely filled with water and then with a cord, as above, the two openings being put into the same two vessels of quicksilver; when the cord is withdrawn

by one of the openings, the quicksilver ascends from the vessels into both the two arms, so that the fourteenth part of the height of the water in one arm together with the height of the quicksilver which has ascended into it is equal to the fourteenth part of the height of the water in the other together with the height of the quicksilver which has ascended into it. The result is that this fourteenth part of the height of the water together with the height of the quicksilver in each arm is a height of two feet three inches; for them the water divides above and there is formed an apparently void space.

From these experiments and many others reported in the complete book, wherein are seen tubes of all lengths, sizes and shapes filled with different liquids, variously immersed in different liquids, carried from some into others, weighed in various fashions, and wherein are described the different attractions felt by the finger closing the tube with the apparent void, there are deduced readily these maxims:

Maxims.

I. That all bodies show a repugnance toward separation one from another, and to allowing an apparent void between them, i. e., that nature abhors this apparent void.

II. That this horror or repugnance of all bodies is no greater toward allowing a large void than a little one; i. e., for separation by a large interval than by a small one.

III. That the force of this horror is limited, and equal to that with which water of a certain height, about thirty-one feet, tends to flow downwards.

IV. That the bodies which bound the apparent void have no tendency to fill it.

V. That this tendency is no stronger for filling a large void than for a little one.

VI. That the force of this tendency is limited, and always equal to that with which water of a certain height, about thirty-one feet, tends to flow downwards.

VII. That a force greater, but as little greater as one chooses, than that with which water of a height of thirty-one feet tends to flow down is enough to cause the sufferance of this apparent void, even as large as one may wish, i. e., to cause bodies to be disunited by an interval as great as one may choose, provided that there is no other obstacle to their separation or displacement except the horror which nature has for the apparent void.

(There then follow eight propositions denying the existence

of a plenum of various imagined sorts and asserting that the "space void in appearance" of the preceding actually contains no known kind of matter, real or hypothetical, including vapors of liquids; then an abstract of the conclusion expressing his opinion, thus:)

Wherefore I shall call a real vacuum that which I have shown as an apparent vacuum, and I will hold for true the maxims given above, and enounce them for the absolute vacuum as I have for the apparent, thus:

(Here follow the maxims above, but with the word *apparent* omitted from connection with *void* or *vacuum*. And, finally, the statement of and reply to certain objections.)

Objections.

I. That the proposition that there is empty space is repugnant to common sense.

II. That the proposition, nature abhors a vacuum and nevertheless allows it, accuses nature of impotence, which implies a contradiction.

III. That numerous experiences, even everyday, show that nature cannot suffer a vacuum.

IV. That an imperceptible matter, unheard of and unknown to all the senses, fills such a space.

V. That light being either an *accident* or a *substance*, it is not possible for it to exist in a vacuum, being an *accident*, and that it fills the space void in appearance, being a *substance*.

(A letter of Pascal to M. de Ribeyre, "Premier président de a Cour des Aides de Clermont-Ferrand," is dated July 12, 1651, in which he complains that in the "Prologue" of certain theses on philosophy read in this judge's presence June 25, 1651, he had been accused of appropriating credit for the Torricellian experiment.

"In the year 1644 someone wrote from Italy to Rev. Fr. Mersenne, Minimite at Paris, that the experiment we are discussing had been done, without specifying in any way who was its author. So in fact he remained unknown to us. Fr. Mersenne tried to repeat it at Paris, and not being entirely successful with it, he stopped and thought no more about it. Then, having been at Rome on other business, and being exactly informed as to the means of carrying it out, he returned thence fully instructed.

This news having been brought us at Rouen, where I then was, in the year 1646, we did this Italian experiment according to the directions of Fr. Mersenne, and, having been entirely suc

cessful with it, I repeated it several times; and being by this frequent repetition entirely assured of its truth, I deduced from it consequences, to test which I did new experiments very different from that one, in the presence of more than five hundred persons of all sorts and conditions, and among them five or six Jesuit fathers of the College at Rouen. . . .

To render to others and myself justice due, I had printed, in the year 1647, the experiments which I had done a year earlier in Normandy. . . . "

(This was the abstract translated above. The complete treatise was never published; only fragments of it are known.—W. J F.)

A POWER TEST FOR PHYSICS PUPILS.

By Willis E. Tower,

Englewood High School, Chicago.

The following test has been used several years at this school. It always arouses interest. Many are surprised at the power required in climbing stairs. A husky football player will develop over 1.5 horse power, while a girl walking upstairs at an ordinary pace will use 0.2 horse power or more. The directions given below are the same as those handed to our pupils.

Purpose: To test the horse power of a person while running upstairs.

Apparatus: A stop watch, a meter stick. (From two to five persons may work together in performing this experiment.)

Directions: (a) Count the number of steps from the first floor to the landing above and find by measurement the average height of each step. Then compute the distance one rises in going up this flight of steps, or determine the height climbed in any other way.

(b) Determine by the use of the stop watch the exact time required to run up the steps, using the average of at least three trials. It may require some practice to learn to use the stop watch properly. Be careful that the watch is started at just the instant the person begins to rise, and that it is stopped just when the person reaches the top. Be careful not to exert yourself unduly in making the test.

(c) Compute the *work done* in running up the steps, using the person's *weight* in *pounds* and the *height* of the stairs in *feet*.

(d) Compute the *power developed* in *horse power* and in *foot pounds per second.*

(e) Place all measurements and results in tabular form. Record the hour and date of making the test.

(f) Make a second test for horse power by going upstairs as before, only this time going at the rate you ordinarily employ. Make three trials and record as before.

Questions: 1. If a man-power is one-seventh of a horse power, how fast should you go upstairs in order to exert just one man-power? How does this compare with your usual speed in going upstairs?

2. How much time did you require to perform this experiment? How much time to write it up?

3. What use can you make of the results of this experiment?

RESEARCH IN PHYSICS.

Conducted by Homer L. Dodge.

State University of Iowa, Representing the American Physical Society.

It is the object of this department to present to teachers of physics the results of recent research. In so far as is possible, the articles and items will be nontechnical, and it is hoped that they will furnish material which will be of value in the classroom. Suggestions and contributions should be sent to H. L. Dodge, Department of Physics, State University of Iowa, Iowa City, Iowa.

THE THERMIONIC VALVE.

By Homer L. Dodge.

If a metal plate is introduced into the bulb of an ordinary incandescent light, the filament of which is supplied with current from a direct current source, and a galvanometer is connected between the plate and the negative terminal of the filament, no current will flow; but if the galvanometer is connected between the plate and the positive terminal, a current of electricity will be found to flow which, it is evident, must pass through the rarefied gas separating the filament and plate. In the first case, the filament is positively charged with respect to the plate and in the second case, negatively charged. The conclusion is that a current[1] of electricity can flow from the plate to the glowing filament but cannot flow from the filament to the plate. Interpreting this in terms of the electron current, we find that negative electrons cannot pass from the plate to the filament under any circumstances but can and do pass from the filament to the plate when the plate is charged positively with respect to the filament, and only then.

The experimental fact which has been described was observed by Mr. Edison about 1884 and is often called the Edison effect. He neither explained the phenomenon nor put it to practical use. It was not until the brilliant researches of pure scientists had cleared the way that the effect was understood. Especially noteworthy in this connection is the work of Sir Joseph J. Thomson of Cambridge and Professor O. W. Richardson of King's College, London, formerly of Princeton University. To the former we are indebted for the discovery of the electron, with all the impetus which this gave to physics. To the latter we are indebted for a large part of our knowledge of "thermionics," or the emission of electrons from hot bodies.

---

[1]The term current (sometimes "positive" current) is used to denote the "flow" of electricity from positive to negative. When the actual flow of negative electrons is specifically referred to, the term electron current is employed. It is an unfortunate accident that the vitreous and resinous electricities of Du Fay were called positive and negative, respectively, by Franklin. If he had made resinous electricity positive, the negative electron would be positive and the flow of electrons would be a positive current.

The first practical application of the Edison effect was made by Professor J. A. Fleming of the University of London, the noted authority on radiotelegraphy and radiotelephony. Fleming had carefully studied the phenomenon at an early date and as a result of his investigations had come to the conclusion that it was due to the emission of negatively charged atoms or molecules from the filament. This was very close to the truth. Later, Thomson's epoch-making discovery revealed the real nature of the negative carriers. Professor Fleming's knowledge of the phenomena was the means, in 1904, of his invention of the oscillation valve which, in its improved forms, is the most sensitive detector of wireless signals which has been developed. How valuable it is in practice can be gathered from a brief consideration of its use, with the telephone, as a receiver.

As is well known, the spark at the sending station sends out trains of electromagnetic waves which produce in the receiving circuit oscillations or alternating currents of extremely high frequency. Such currents, if sent through a telephone receiver, cannot actuate the diaphragm because of their high frequency. The diaphragm cannot follow them and even if it could, the pitch of the resulting sound would be so high as to be inaudible. Two things have to be accomplished: The alternating currents have to be rectified so that a train of waves appears in the telephone circuit as a unilateral gush of electricity and these gushes have to follow each other at the proper frequency. The operation is as follows: Each spark at the sending station sends out a train of waves of radio frequency. By means of a rotary spark gap these groups are made to follow each other at a definite frequency, usually 500 to 1000 per second. Oscillating currents are induced in the receiving circuit which are rectified by the valve. Thus each group of waves becomes a unilateral flow or pulse of current and these pulses follow each other with the frequency of the rotating spark gap at the sending station and produce a corresponding note (pitch of 500 to 1000) in the receiver, this range being chosen because of the high sensitivity of the ear in this region. If the key at the sending station is held down for a short time a correspondingly small number of groups of waves is sent out and the note in the receiver is heard for a short time, making a "dot." If the key is held down longer, the note continues and forms a "dash." From these considerations, the value of an efficient rectifier as a part of a wireless system is apparent.

The Fleming valve, in its original form, consisted of an exhausted glass bulb having a carbon filament sealed into it as in a lamp, and also a metal plate carried on a third terminal. The filament was made incandescent by an insulated battery and the oscillation circuit was connected to the metal plate and to one terminal of the filament. Experiment showed that the valve rectified the oscillations, permitting the movement of the electricity in one direction only, through the vacuum between the hot filament and the plate, this direction being the one which required movement of negative electricity from the filament to the plate. One must be careful not to confuse the two circuits. The battery which heats the filament is merely incidental. Any other means of raising the filament to a high temperature would do as well. This battery is of low voltage, is thoroughly insulated, and has nothing to do with the current in the main circuit.

The simple explanation of the oscillation valve is as follows: All metallic conductors are supposed to contain free electrons, i. e., electrons which are not attached to particular atoms or molecules, even though there exist strong forces which tend to hold them within the boundaries of the body. These electrons are in thermal agitation in exactly the same way as are the molecules, and "evaporate" from the surface in much the same fashion. The process of evaporation, as is well known, occurs through the escape, at the surface, of those molecules which happen to have sufficient kinetic energy to enable them to break the bonds of molecular attraction. The average kinetic energy of the molecules is a function of temperature but the kinetic energy of any particular molecule is a matter of chance and is constantly changing. Thus there are some molecules moving at very high speeds and others at correspondingly low speeds. Similarly, the average kinetic energy of the electrons is a definite function of temperature with some moving faster and some slower than the average. Now and then an electron will acquire sufficient kinetic energy to enable it to break through the electrical attraction at the surface and escape into the surrounding space. Accordingly, a hot body is a source of a copious supply of electrons.[2] These electrons are free to go to any neighboring positively charged body or to return to the source in case it is positively charged.

Thus we see that if a hot and a cold body separated by a rarefied gas are made a part of an electric circuit, there are car-

[2]Tungsten at a temperature of 2000°K. emits twenty million billion thermions (negative electrons) per second per square centimeter, corresponding to a current of three milliamperes.

riers ready to complete the circuit through the gas in the one direction but no carriers to conduct the current in the other. The resistance of such a device to the flow of current in the one direction is comparatively small, while in the other direction it is, for all practical purposes, infinity. Such a device, inserted in a circuit which would otherwise carry an alternating current, will permit the current to flow in one direction only. Hence the name, thermionic valve.

THE FIFTH LIBERTY LOAN.

A large percentage of the money which will be subscribed to the Fifth Liberty Loan will go toward the rehabilitation of wounded men. The United States Government is resolved to do its utmost to restore every wounded American soldier and sailor to health, strength, and self-supporting activity. He will not be discharged from the hospital until all the medical and surgical treatment necessary to restore him to health has been given him, under the jurisdiction of military or naval authorities, according to the branch of service he is in.

Then his future will be considered by the Federal Board for Vocational Education. If he has been disabled in such a way that he cannot take up the work he left to go into the country's service, a large vocational field is opened up to him, with a wide choice of occupations. He is carefully trained to self supporting activity.

If he needs an artificial limb or mechanical appliance, the Government will supply it free, keep it in repair, and renew it when necessary. If, after his discharge from the hospital, he again needs medical treatment on account of his disability, the Government will supply it free. While he is in the hospital and while in training afterwards the soldier or sailor will receive compensation as if in service and his family or dependents will receive their allotments.

Also, a wounded soldier or sailor, regardless of whether his disability prevents him from taking up his former employment, may take a course in vocational training, free of cost, and the war risk insurance compensation will be paid him during the time of training. In this case no allotment will be paid to his family.

The training branches, with their thousands of trained instructors, will use millions of the nation's dollars, and the country, instead of being filled with dependent cripples and beggars, an eyesore to the nation and a constant reminder of the horrible side of the great war, with its glorified cause and its magnificent victory, will have thousands of highly trained men—heroes, the glory of whose sacrifice will not have been tarnished by a moral and mental disintegration.

That's one of the reasons why the Fifth Liberty Loan must be oversubscribed. The first three loans launched America in the war—built training camps and equipped and sent men overseas; the Fourth Liberty Loan, the "fighting" loan, backed up the fighting men and made overwhelming victory for the Allies possible. The Fifth or Victory Loan will be just as important in the annals of war loans, for both moral and material reasons. America would be monstrously ungrateful should she not stay with her men in khaki and blue until they are returned to their homes, physically strong and able to earn a livelihood. The best way for every person to show his personal gratitude is to start now planning how much he can subscribe to the Fifth Loan.

THE ROLE PLAYED BY GENERALIZATIONS IN LABORATORY PHYSICS.

By W. A. Shewhart,
Western Electric Co., New York City.

Reflection upon the history of civilization reveals at once that one of the chief aims of the human race has been a search for things or principles that remain invariant. If we study the history and philosophy of man, if we thoughtfully look about us, if we reflect upon the cravings of our own mind, we shall see that in every department of human interest and activity the supreme enterprise has been the quest for constance in a world of change, a search for permanence in a world whose law is variation. This is natural, for consider man plunged into the depths of the sense world of force and matter, surrounded by innumerable and apparently unrelated phenomena, torn and tossed among the elements of the cosmic stream which originates he knows not where, and flows he knows not whither. The aim of man has been to gain some everlasting vantage ground, some abiding rock from which to view and study the great ebb and flow of material events.

Look, if we please, at what we call science, philosophy, theology and art, and it is evident that these are greater forms under which various conquests for abiding realities have been carried on by previous generations. Confining ourselves to the domain of only a fragmentary element of the far greater domain of science, that is, considering the subject of physics, we find that the same aim has spurred on human endeavor that has underlain advancement in general. Lives of all great physicists remind us that theirs has been a search for permanence, a groping for abiding principles which would serve to correlate the great mass of worldly phenomena. Amid the infinite variety of nature many things appear as common, others as perplexing and seemingly unexplainable. The search for the elements which remain the same throughout the great multiplicity of phenomena has resulted in the real progress that has been made in physics.

It is the common observation of the teaching profession that the young student usually finds difficult those same points which have proven stumbling blocks to the greater physicists. Each adventurer, in his struggle to attain this vantage ground from which to view the phenomena, must expect to often slip and lose his footing even at the beginning of the course, even though the generations which have trod before him discovered and pointed

out many well established principles which serve as guide posts. He must acquire for himself the skill of recognizing the permanent elements throughout the greatest range and variety of phenomena. "This ability," to quote Professor E. Mach,[1] "leads to a comprehensive, compact, consistent, and facile conception of facts."

The first period in the study of science may be designated as the period of survey and discovery in which the student must needs become acquainted with a large mass of facts. He must read of experiments and make experiments for himself, gathering all the while a store of concrete and vivid perceptions from which to draw in his later work, but it would be a hopeless task to undertake to remember and keep in mind this great body of data. Many physical quantities, such as velocity, mass, force, energy, etc., have been given names and in order that a new adventurer in the domain of physics may profit by the written and spoken words of others, he must memorize the accepted definitions of these terms as he would the vocabulary of a foreign language.

It is true, however, that physics is often taught as a heterogeneous body of unrelated facts and the student who has taken an elementary course, either in high school or college, looks back upon his work and remembers only a number of isolated facts, for he has not formed a conception of the principles relating these facts, and cannot think physics.

Therefore, the next step in scientific advancement is to pick out the common elements in the various experiments and include these under certain generalizations or, to again quote E. Mach,[2] "Thence is imposed the task of everywhere seeking out in the natural phenomena those elements that are the same and that, amid all multiplicity, remain the same."

The third step should be a critical study of the generalizations and a discussion of their applicability to all phenomena. Many such principles have practical limitations, as in the case of the general gas law, $pv = RT$, where p is the pressure, v the volume, T the absolute temperature and R a constant. As has long been known, this applies only approximately for real gases, and a study of its limitations is necessary for a thorough appreciation of the principle. In fact, as has often been pointed out, what we sometimes call physical laws are not laws in the sense that they present the whole truth of nature, but that they represent only a generalization based upon a finite number of observations.

[1]Mach, *Science of Mechanics*, page 5.
[2]E. Mach, *Science of Mechanics*, page 5.

Thus, we must note the difference in reasoning from principles based upon experiment and postulates of pure reason, for in the limit we do not know whether nature is based upon a rigorous or chance basis.

If the study of physics is to lead ultimately to a critical study of generalizations, then the laboratory work must lend itself to this end, by acquainting the student with physical quantities and phenomena which should give him clear-cut perceptions which, under the leadership of the teacher, should form the groundwork for the conceptions which may be gathered together as generalizations. Furthermore, it should lead the student to acquire the proper viewpoint from which to approach an investigation, be it either scientific or technical, and the ability to recognize the essentials of the problem at the outset.

In the laboratory, we must choose between the two-horned lemma—performing a large number of experiments in a cursory way, or of performing a fewer in a more thorough manner. The former gives a student a chance to gather a few facts; the second develops the student's individuality and encourages him to make generalizations and to discern the abstract principles underlying the concrete phenomena and in the end encourages the student to think.

For example, in the group of experiments ordinarily performed under the general heading of elasticity, it is not sufficient to know that the stretch l of a wire of length L and cross section πr^2 subjected to a tension F is given by $l = \frac{cFL}{\pi r^2}$ where c is a constant, depending upon the material of which the wire is made, or similarly that θ, the angular twist in radians for a rod of uniform cross sectional area πr^2, and length L, fastened at one end and subjected to a torque FR at the other is equal to $\frac{2FRL}{\pi r^4 k}$ where k is a constant called the coefficient of torsional rigidity.

A study of experiments of bending and twisting rods or stretching springs is incomplete unless in addition to such concrete facts, certain generalizations are made, as indicated below.

Such a study should lead to a definite conception of strain and stress and of the general relation between them, called elasticity, for this is a vantage ground from which to view most elastic phenomena. For instance, the general terms may be defined in the following manner: Whenever a body undergoes

change in size or shape it is said to be strained. If the strain is of the simplest class, where two equal straight parallel lines go over into two equal parallel lines, it is called homogeneous; the most general type of such a strain being resolvable into a strain which changes the size but not the shape and one which changes the shape but not the size. If we consider the body under strain, the forces per unit area resisting the forces producing the strain are called stresses. The most general stress can be resolved into a tangential and a normal component, both of which are measured in terms of force per unit area. The relation existing between these two quantities is given by Hooke's Law, which states that stress is proportional to strain, within the elastic limit, or that when the load increases or diminishes the measured strain increases or diminishes in the same ratio, and when the load is reduced to zero no strain can be measured.

Thus we may write: stress = c strain. The student should grasp the generalized meaning of the constant c, for he should see that the types of stress and strain may be defined in different ways, and that we may express the strain of any of these types that accompanies a stress of the corresponding type, when there is no other stress, by the above equation, where c is called a modulus of elasticity. If the strain is a change in size but not shape, and the stress is a uniform normal pressure, the constant c is called the bulk modulus of elasticity, but if the strain is one of shape only, the constant of proportionality relating this strain to its accompanying stress is called the modulus of simple rigidity.

Since any homogeneous strain may be decomposed into a shear changing the shape and a single contraction or expansion changing the volume, if we know the two moduli of elasticity corresponding to these we may calculate all others, such as Young's Modulus, which may, for example, be shown to equal $\frac{9nk}{3k+n}$.

In generalized terms, Hooke's Law may be stated thus: "Each of the six components of stress at any point of a body is a linear function of the six components of strain at that point." From this statement a group of equations may be set up which form the basis for our present mathematical treatises on elasticity. From a critical viewpoint it should be noted that there is much room for future work, for the present theory of elasticity does not hold beyond the elastic limit nor does it rest upon the ultimate nature of the structure of materials. The student of

physics should therefore gain a clear conception of principles involved in experiments which he is performing in the laboratory in addition to gaining a hold on facts, and the teacher should have these same conceptions when teaching.

If the chief aim of the human race as reflected in the collected works on science, theology, etc., has been a search for invariance in a world of change, then as progress in physics is but a single unit of the progress of civilization, it must reveal a search for invariance, the somewhat satisfactory heights of attainment being marked by such principles as conservation of energy, conservation of linear and angular momentum, a generalized statement of Hooke's Law, etc. In order to see physics as a single unit we must endeavor to attain some vantage ground from which to view all physical phenomena in their relation one to another. Many and far-reaching though the known principles of physics are today, lending an insight into a multitude of physical phenomena on every side of us, guiding us onward amid the flux of things material, yet we must recognize, perhaps more than ever before, the height of the wall of unknown and unrelated facts which surround us today.

In every field of physics much has been done, but there remains much more for the future generations to do. Just insofar as a student acquires a definite and clearly defined conception of the principles of physics and is enabled by these to relate and show the interconnection and interdependence, he has fitted himself to force on towards the final goal of science.

POTASH PRODUCTION INCREASING.

The situation in respect to potash is improving, the rate of production during the first six months of 1918 having been equal to nearly twenty-five per cent of the normal consumption. By force of circumstances the country is now essentially independent of foreign importations, though at an undetermined cost in the fertility of the soil. Searles Lake, in California, the alkali lakes in western Nebraska, and the alunite deposits of Utah, all of which were examined, with favorable recommendations, in earlier reports by the Geological Survey, Department of the Interior, are now our principal sources of supply. From these, as well as from various by-product recoveries, larger and increasing supplies are expected in the latter half of 1918 and in 1919.—[From Annual Report of Director United States Geological Survey.

MATHEMATICS AND ANTI-MATHEMATICS.

By C. E. White,
Buckhannon, W. Va.

We have a few educators in this state who give much encouragement to the movement against mathematics as a required subject in the high school and who try to persuade our present and future teachers and our school officials that mathematical training does not have sufficient value to justify requiring it in the high school. Answers to letters of inquiry as to mathematical requirements indicate that they have had but little effect so far. But lest their attacks, unopposed by those who should defend mathematics, may cause a few school officials who do not have the leisure to investigate the soundness of their arguments to accept them at their face value, the writer believes that these officials should have their attention called, frequently, to the arguments in favor of mathematical requirements.

This article is written in defense of mathematics. This defense will be made in two ways: first, by showing that the claims that have caused mathematical subjects to be venerated by the laity and to be considered strong fundamental subjects in education by the great majority of educators are valid; second, by pointing out the weakness of the arguments against mathematical requirements.

What school subject has given to man greater power to accomplish great things than is given him through mathematics? After Uranus was discovered and its orbit computed, it was found that the planet deviated two minutes from the path that had been computed for it. Two minutes is an arc so small that two stars that close together would be seen as a single star. But mathematics is so accurate and truthful that Leverrier of France and Adams of England took up the problem of finding the cause of this slight discrepancy between observation and calculation and after a long computation, using the power given them by algebra, geometry, trigonometry and calculus to be found in a text on theoretical astronomy, they were able to tell the astronomers where to point their telescopes to find a new world—Neptune was found.

Much might be written to show how the power of mathematics is made manifest in the domain of science. The relation between science and the "Mother of Sciences" is so close that practically all great scientists have been able mathematicians,

and the growth in any science, pure or applied, depends to a marked degree upon the contributions made by mathematics. The four greatest scientists that England has produced, according to the Encyclopedia Britannica, are Sir George Stokes, Lord Kelvin, James Clerk Maxwell, and Lord Rayleigh. Each of these men contributed much to mathematics. Stokes, Maxwell, and Rayleigh won mathematical honors and prizes in the mathematical tripos examinations. Previous to becoming a professor of science, Kelvin was Professor of Mathematics in the University of Glasgow and Stokes was Professor of Mathematics in the University of Cambridge. Maxwell's *Mathematical Theory of Electricity and Magnetism* was not only a valuable contribution to science but also to mathematics. Concerning astronomy, Sir J. Herschel said: "Admission to the sanctuary and to the privileges and feelings of a votary is only to be gained by one means, sound and sufficient knowledge of mathematics, the great instrument of all exact inquiry, without which no man can ever make such advances in this or any other of the higher departments of science as can enable him to form an independent opinion on any subject of discussion within their range."

The great engineering works are monuments testifying to the power given man through mathematics. Recently I received a large pamphlet from Rensselaer Polytechnic Institute giving half-tone engravings showing some of the engineering work done by graduates of that school. Turning its pages, I observed many great bridges and buildings, canals, a war vessel, ocean liners, railroad terminals, and portions of the two hundred thousand miles of railroad which they had helped to construct. I observed drainage maps, and geological maps they had made, and much machinery they had invented and installed in factories. Civil, mechanical, electrical, and chemical engineering requires much mathematics. Many an engineer who would not have been an engineer if mathematics had not been required in high schools and colleges has worked on great irrigation projects, drainage and life saving projects; on canal, railroad and highway construction; on gigantic buildings and bridges; on the intricate engineering work of a great city; on the construction of merchant vessels, war vessels, and the machinery used in our factories; in locating deposits of coal, gas, oil, copper and iron; and, in many other ways has contributed to the greatness of the nation.

Mathematics has great value in the domain of inventions. Although the Edison Company has able mathematicians on its staff, it was looking, recently, for a mathematician of fine ability. A machine to be efficient must have its mathematics right. Many great inventions are the products of mathematized minds. Engineers have contributed much in the way of inventions. Great engineers put the whir in the liberty motor that has made dreadful sounds for German ears and contributed much to victory for the allies and democracy.

Had England a number of years ago listened to the tirades on mathematics by William Lock and had France failed to have observed the injunction of Napoleon, "the advancement, the perfection of mathematics are bound up with the prosperity of the state," Germany would have taken Verdun, would have taken Paris, and would have won a decisive victory on the western front the first year. The Kaiser did not get to eat his Christmas dinner in Paris in 1914 because the English and French engineers were able to compete with the German engineers. Modern war is of such a nature that the war in Europe was in many respects an engineering contest. "The engineering problems of the great war stagger the imagination." One of the most stupendous engagements of the mighty battles of the great war, the battle of Messines Ridge, was won by the engineers who skillfully tunnelled the ridge and placed the explosives under the first line trenches of the Germans. In modern war the general commanding a large force who does not have ability as a military engineer is incompetent. It is said that the French and English had control in the air on the western front because English mathematicians solved certain problems pertaining to dynamics of flight which led to the improvement of the airplane. Recently I read: "Dr. Nichols of the University of Virginia has rendered a valuable service to his country and made a valuable contribution to mathematics by solving an equation of the ninth degree pertaining to ship building." By the accurate measurements of the two holes made in two awnings in Paris by a shell from a "wonder gun," military mathematicians were able to locate the gun and to give range to French artillery that destroyed three of these guns. The value of mathematics in warfare is especially emphasized by the mathematical requirements for entrance to and graduation from military and naval schools.

Pease, Postmaster General of England, said: "England has

been slow about recognizing the value of men of science to the state while Germany years ago, to the great loss of other nations, recognized the value of her men of science to the state." Secretary of War Baker wrote Dr. Hollis Godfrey that he deplored students leaving school to join the army except when drafted, and pointed out the increasing need the Government would have for men who have taken courses in science and engineering. Science, technology, and medicine, the subjects that contribute most to make a nation strong in times like the present, cannot be emphasized as they should be unless mathematics is emphasized in the high school.

Algebra and geometry are strong fundamental subjects in education because they open the door to a great and valuable field of knowledge, and because they have a cultural and disciplinary value that is quite different from that given by any other high school subject. It would take pages to write down all the subjects that these subjects are tied to as prerequisites. They are not only prerequisites for more advanced courses in mathematics but also for a large number of courses that would not be classified as mathematics. The value of any other high school subject as a prerequisite is small in comparison. About one-half of the students enrolled in higher institutions of learning are taking courses in technology, science, and medicine, and these subjects require algebra and geometry as prerequisites. This fact alone makes it worth while that mathematics be required in the high school. If we add to these the number required to meet entrance requirements in these subjects, we will find that over ninety-nine per cent of the students enrolled in higher institutions have been required to present these subjects for credit.

The high school or college that does not have mathematical requirements fails to emphasize the value of a liberal education. There are many articles in popular magazines that could not be read without a knowledge of high school mathematics. There are a large number of articles in the Encyclopaedia Britannica which are intended for the general reader that could not be read without a knowledge of these subjects. Prof. Mason has made the observation that there are one hundred and four articles in the Britannica one could not read without a knowledge of calculus and that one could not read the articles on the clock, sewing machine, map, sky, steam engine and seventy other articles that would not be classified as mathematics without a knowledge

of calculus. In the Library of the Naval Observatory at Washington there are more than twenty-seven thousand volumes one could not read without a knowledge of secondary and college mathematics. Since mathematics is one of the great fields of knowledge, since high school mathematics lays the foundation for work in this field and in the great field of science, since it gives training in deductive reasoning and rigorous thinking as no other subject does, a curriculum emphasizing a liberal education should emphasize this knowledge, this foundation and this training by requiring mathematics.

To ignore the importance of mathematical requirements in the high school is to ignore disciplinary values in education, and to ignore disciplinary values is to belittle the value of an education. This would be made very evident if the alumni of any institution were given an examination to find out what they know of what they are supposed to know. If school subjects have disciplinary values, it is as absurd to say that one subject has the same disciplinary value as another as it would be to say that five equals one or to say that exercising the right arm will strengthen the left. A freshman recently said to me, "I like mathematics and chemistry because they make a person think. I can get the lessons in the two other subjects I am taking by reading them over once." Is it reasonable to conclude that the two other subjects will give this student the same amount of mental discipline that mathematics and chemistry will give? Two school subjects may differ, both as to the amount of mental activity required and as to the kind of mental activity required. The mind to be well disciplined should have much training in the different kinds of mental activity.

Mathematics is better adapted than any other high school subject for the purpose of cultivating the reasoning powers because it is problematical in nature, because mathematical reasoning does not tax the memory as reasoning in other subjects does; because the symbolic language of mathematics is better suited to the purpose of reasoning than any other language; because mathematical reasoning leaves no place or opportunity for error to creep in to mar or vitiate the derived truths; and because of the emphasis it gives to accurate and logical reasoning. "From the specific habits of accuracy and close reasoning developed in the school exercises in mathematics one comes gradually to idealize accuracy and close thinking as methods of procedure that will bring desirable results in other fields."

"Lincoln, when he was practicing law, gave much time to the study of geometry in order that he might learn to reason more accurately and logically." Mathematics gives training in inductive reasoning as well as in deductive reasoning; for, a large per cent of the problems are solved by the inductive process.

The mind grows, not by doing the things that are easy to do but by doing the things that are hard to do. The mind grows by vigorous responses to the challenges that are made to the higher thought processes. And no high school subject gives these challenges as geometry does. The student of geometry has the opportunity of solving problems that would have made a student of the Alexandrian School famous.

It may be individualistic to let a student drift in his own careless way and require nothing in school but a four years' stay, but it is more humanistic to emphasize scholarship and the strong fundamental subjects in education. In commenting on certain theories in education, Dr. Münsterberg in the Metropolitan Magazine, 1910, says: "The community has found out that such schemes may be well fitted to give the children a good time at school but lead them to a bad time afterward. Life is hard work and if they have never learned in school to give their concentrated attention to that which does not appeal to them and which does not interest them immediately, they have missed the most valuable lesson of their school years. It can always be found that it is the general education that pays best and the more the period of cultural work can be expanded the more efficient will be the services of the school for the practical services of the nation."

The consensus of opinion is that mathematics should be required in the high school. This was conclusively shown by answers to letters of inquiry sent out by Prof. Hancock of Cincinnati University, Prof. Johnson of the U. S. Navy, and a committee of Chicago teachers. Prof. Hancock sent letters to the most prominent business men, lawyers, and doctors throughout the country and ninety-one per cent advocated requiring mathematics. Prof. Johnson sent letters to a large number of persons whose names are found in "Who's Who" and over ninety-one per cent favored mathematical requirements. The Chicago committee sent letters to prominent men in Chicago and elsewhere and received replies that give evidence that is overwhelmingly in favor of mathematics being required in high schools. According to the last report of the commissioner of

education, 49.3 per cent of the total enrollment in high schools are enrolled in algebra classes and about 27 per cent in geometry classes, which shows that practically all of the high schools are requiring one and a half or two years of algebra and one of geometry, and it also shows that the movement against mathematics as a required subject is confined to a few small areas. I have examined the catalogues for the year 1917 of seventy-six universities and colleges and I find that over three-fourths of them require two and a half and three years of mathematics for entrance; that the others, except one, require two years for entrance, and that one requires two years for graduation, which is practically the same thing as requiring for entrance; for the courses are not offered as college courses. The above observations show that a great majority of educators in high schools, colleges, and universities favor mathematical requirements in the high school.

He who thinks that experimentation in psychology has proven anything pertaining to the question of requiring mathematics in high school should read Dr. Moore's article, "Disciplinary Values," in the *Educational Review*, October, 1917, in which he shows the weakness of the arguments of the theorists who wish to revolutionize our educational system and the falsity of the conclusions derived from limited and imperfect experimentation. He should read Dr. Young's two articles bearing on the attacks upon mathematics and printed in SCHOOL SCIENCE AND MATHEMATICS for January and February, 1918. He should read Dr. D. E. Smith's "Mathematics in the Training for Citizenship," *Teachers College Record*, May, 1917. The above and other writers give emphasis to the following by Professor Paul Shorey: "But these men (O'Shea, Bagley, Horn, Thorndike, and De Garmo) are cited not as authorities but as experts who have proved by scientific experiment and ratiocination that mental discipline is a myth. There is no such proof, and no prospect of it. There are, in general, no laboratory experiments that teach us anything about the higher mental processes which we cannot observe and infer by more "natural methods." Practically all the experiments in psychology worth mentioning pertain to memory and give emphasis to the law of association in memory. As a mental activity, reasoning differs so much from memory that any conclusion derived by inferring that reasoning is like memory is based on false premises.

He who is inclined to give much emphasis to the conclusions that have been derived pertaining to transfer of training by

means of the coefficient of correlation should read Dr. C. N. Moore's "On Correlation and Disciplinary Values," *School and Society*, September, 1915. In this article, Dr. Moore shows that the claim that there is very little connection between ability in one field and ability in another field is not a valid one by showing that the literature on correlation does not furnish a sound basis for any very definite conclusions and that it does not support the above claim but furnishes some evidence in the contrary direction. The anti-disciplinarian should also read Dr. Moore's "On the Coefficient of Correlation as a Measure of Relationship," *Science*, October, 1915, where it is proven mathematically that the coefficient of correlation is not a satisfactory measure of all forms of relationship. Dr. Moore has computed the correlation coefficient for successive grades in algebra obtained by a group of 254 boys and another group of 198 girls and found the values of the coefficients to be 0.71 and 0.65. An anti-disciplinarian would interpret this as meaning that 0.71 of the ability of the class was equal to the ability of the class and an anti-mathematics propagandist would interpret it as meaning that one should not study mathematics for more mathematics but Dr. Moore says: "When the correlation coefficient for successive grades in the same subject may be 0.7 or less, it is apparent that there is absolutely no basis for the statement that there is little relation between subjects the grades in which yield a correlation coefficient of 0.5 or more." Spearman gave correlation coefficients obtained for the four subjects, classics, French, English, and mathematics, ranging from 0.64 to 0.83, which indicate, if they indicate anything, a close relation between mathematics and these subjects.

Statistics pertaining to grades made on college entrance examinations probably do show that some students have not done their work in high school mathematics and languages as well as they should, but we might expect this because a certain per cent of high school students are loafers on the job and mathematics and the languages are the high school subjects that require time and studious habits in the preparation for such an examination. But there are other reasons why we might expect failures in mathematics. Two-thirds of those who try the examinations have done their preparatory work at home or in private schools, and for that reason many have given much less than one year to geometry. The examinations emphasize problem solving while many teachers do not give the proper emphasis to problem solving in geometry.

Dr. Flexner, who makes use of statistics in his arguments, makes no complaint with respect to first year algebra. A large per cent of those who try the examination in advanced algebra have not given sufficient time to the study of algebra to qualify them to pass such an examination. Many have prepared by taking short courses in private schools or under private instruction. Moreover, at a conference of members of the College Entrance Board and high school teachers in 1916, it was decided that the average student could not qualify for that examination in a half year and that one year should be given to advanced algebra and one unit instead of one-half unit entrance credit given. "Dr. Flexner's figures eliminate most or many of the better students who take the examinations of the particular institutions they enter or who enter by the certificate plan." If these statistics indicate anything, they indicate carelessness on the part of teachers of mathematics in passing students and this should be corrected by more conscientious work on the part of teachers and by greater care on the part of those who employ teachers to get teachers that are well qualified to teach the subject. Too often do we find persons teaching mathematics who are not well prepared to teach the subject.

We do not claim that mathematical training is a prime requisite for all fields of endeavor or that it will insure success in any field of endeavor, but we do claim that general observations prove that it is a valuable factor in the preparation for many professions; that general observations prove that it increases the power to reason; that the concentration, will power and close reasoning required in solving mathematical problems will contribute to effective work in other domains; that it causes the student to use his own powers independently in an effort to fathom the cause of things; and that such training is necessary to prepare the student for the university and its sciences. We do claim that the high school student needs this training, not only for the disciplinary values and the practical values that have previously been stated, but also because it gives him greater ability in the most practical of all subjects, arithmetic. Algebra deals with the general operations with quantity of which the arithmetic operations are particular cases. Mensuration in arithmetic is geometry, and the student who solves a few of the hardest geometric problems in Ray's *Higher Arithmetic* will do more deductive thinking, more hard thinking, more rigorous thinking, more logical thinking, and more original thinking than he must do to pass on a whole year's work in some subjects that might be mentioned.

THE TEACHING OF FIRST YEAR ALGEBRA.[1]

By William W. Strader,

W. L. Dickinson High School, Jersey City, N. J.

Algebra in the first year of the high school should be so outlined in its course that it will prove sufficient for three classes of pupils. Some pupils will continue through high school into college; others will continue high school in a commercial or technical course; a great number will have completed their school work at the close of the first year. Algebra should give something to each of these.

In order to meet such requirements our aim should be to attain six goals. We should seek:

1. To extend the theoretic development of arithmetic.
2. To strengthen and facilitate computation.
3. To apply the equation to a wide range of problems.
4. To furnish principles which will make geometry, chemistry, and physics more usable.
5. To cultivate the intelligent use of formulas.
6. To introduce the idea of function.

Material through which our road runs is found in the usual text of the day or can be supplied by any interested teacher. It may be well here to state a desirable order and list of topics so that the material may be judiciously selected. You will note some few omissions and several additions as found in the "classic" course in algebra.

I. We should have an introduction which includes numerical substitution, simple equations formed from easy problems (solved by arithmetic analysis) and the introduction of zero and negative numbers.

II. The four fundamental operations, with considerable stress placed upon graphic addition and subtraction.

III. Insertion and removal of parentheses (not more involved than one within another).

IV. Simple equations.

V. Simultaneous equations of the first degree solved by substitution only.

VI. Special Products.

VII. Factoring:
1. $x^2 \pm 2xy + y^2$
2. $x^2 - y^2$
3. $x^2 + bx + c$
4. $ax + ay + az$
5. $ax + ay + bx + by$
6. $ax^2 + bx + c$
7. Factor theorem.

VIII. Uses of Factoring:
1. Solution of equations.
2. Reduction of fractions to simplest terms.
3. L. C. M.

IX. Four fundamental operations with fractions. (The work on ratio to be included here).

X. Fractional equations.

XI. Simultaneous equations of the first degree and their graphs.

XII. Square root of numbers and algebraic expressions.

[1]Read before the association of Mathematics Teachers of New Jersey in Newark, Nov. 25, 1916.

XIII. Simple radicals (as may be expected in quadratics and plane geometry).
XIV. Quadratic equations solved by factoring and formula only.
XV. Formulas—their transformations and evaluation.
XVI. Graphics.

But before beginning the scheme of topics just listed it would be well to teach the pupils a little arithmetic. It surprises the teachers of first year algebra to find how little their pupils know. Of accuracy, the pupils know little; of analysis, less yet; and of mechanical operations, a great deal. Two weeks' work in the four fundamental operations with integers and fractions will be well spent. This proves to be a time saver, too, for algebraic terms and methods can be introduced while the pupils are upon familiar ground.

In teaching addition and subtraction of positive and negative numbers in algebra, we begin by establishing a complete scale with zero as the mid-point. All the numbers to the right are above zero, that is positive, and numbers below the zero are negative. Positive direction is already a familiar idea (familiar from everyday experiences) and we teach that negative direction is the opposite of positive. A few familiar illustrations of these numbers and directions should be presented to the pupils as old friends. Care should be taken not to present too much, for a multiplicity of definition and illustration will tend to confusion. There is such a thing as "masterful inactivity."

In arithmetic I have found it of advantage to teach the addition of fractions, whose denominations are 2, 4, 8, 16 and 32, on a rule by sliding the thumb along the required distance for each fraction. Where the thumb comes to rest is the sum. I know of "practical" men who are able by this method to glance the sum of a fair variety of fractions. This seems to be a good way to begin our addition in algebra. It is not difficult for pupils to understand that the sum of several numbers is the direction and distance that the resulting point is from zero. Thus we include positive and negative sums (results). We give in this work to the sign of addition the meaning – and from this point we take, to illustrate: $3+2$ means from a point 3 spaces to the right of zero we take 2 more spaces to the right of zero and we rest now at a point 5 spaces to the right of zero. In $-3+2$, we rest at a point which is 1 space below zero, etc.

In the pupils' experience they have already met the term "difference in latitude and longitude" as meaning the distance between certain given places. If to this we attach the idea of

direction we have a working basis for graphic subtraction. The difference between two numbers is defined as the direction and distance from the subtrahend to the minuend. In the classroom I have characterized the subtraction of b from a as traveling from station b to station a. "Which way did we go?" gives the sign and "How far did we go?" completes the result. Pupils like to take these imaginary journeys.

I advise following this graphic addition and subtraction to quite an extent. To "change signs and add" offers a shorter but a more mechanically applied method of subtraction. Later on in the work it fills a place if the pupils so desire it, but in the beginning the graphic work suggested above helps the pupils to recognize the ordinal value of negative numbers and to appreciate the double significance of plus and minus signs.

Unfortunately, when we seek a clear explanation of the law of signs for multiplication, we seek in vain. A push and pull of values on scales—repeated addition and subtraction numerically or graphically explained—or, defining that the product of $a \times b$ is the same as the result obtained when a is operated upon in the same manner as unity was operated upon to obtain b—these all deepen the difficulties. Experience has shown that "Like signs give plus" and "unlike signs give minus." Stated as suggestions or as rules it matters not; what does matter is that pupils know and use these catchy expressions, long familiar. What we need at this point of the work is a thoroughness in the pupils' practice and not so much attempted thoroughness of teachers' expositions.

Since the equation is the backbone of first year algebra, we should see that its formation and solution are properly handled. In the beginning the solution is brought about by arithmetic analysis, which should be continued until the transformation axioms are introduced and understood. To transpose by changing signs gives no reason for the transformation. Far better is it to go back to the restoration method of Al-Khowarazmi. In fact, I have used such a method in the classroom to advantage. After the multiplication axiom has been given, solution by analysis need not be continued. It is better though, even now, to have pupils tell exactly what has been done than to allow such omnibus terms as transposing, collecting, simplifying or combining.

Of course, we will insist that an algebraic equation must contain an unknown quantity whose root or roots satisfy the

given expression. This verification will be simplified if the test of equivalency is applied as the solution progresses.

Real applied problems in first year algebra are scarce, since everyday affairs do not offer many problems in which algebraic treatment is necessary. Problems may be clothed in terms which make them seem real and this deception (?) may add interest. The bulk of the subject matter will come from money, percentages, distances, time, weight, etc. Pupils readily write out "written problems" and in turn find their solutions.

I have found that pupils appreciate these suggestions in working problems:

1. In general, the *number* in question is represented by x (or some other letter).

2. Two expressions may be found which represent the same quantity.

3. The expressed equality between these two expressions is an equation.

4. The roots of this equation must satisfy the problem itself before the problem is said to have a solution.

To keep constantly in mind what is given and what is required seems to be quite easy but pupils fail to do this. Such inattention is shown by their difficulty in forming the equation and by their failure to find a second number when two numbers are required for a solution.

Such a simple suggestion as $7 \div 3$ gives 2 and a remainder of 1 has been of value to classes when dealing with divisors, quotients, dividends and remainders. So also may any simply formed example which uses small integers help in other problems. If pupils will only cultivate the habit of forming such examples themselves, they could answer many of their own questions. They will not only analyze problems with more facility but they will develop more power and confidence.

In teaching factoring we lay emphasis upon the fact that a product is made by numbers whose law of combination is multiplication. We impress the idea that "factors are makers" but we slight the idea that a factor is an exact divisor. We may infer this last. We may even mention it but we fail to use it enough. If we do use it, the term cancellation may be done away with. We thus avoid the often repeated example of

$$\frac{\overset{a\ +b}{\cancel{a}^2-\cancel{b}^2}}{\cancel{a}-\cancel{b}} = a+b,$$

which gives the correct result by a wrong method. Then, too, if we teach that a factor is an exact divisor, we pave the way for an easy understanding of the remainder theorem.

Just what methods a teacher may use in teaching the cases of factoring will depend upon his own peculiar hobby and so will depend his success. In the general quadratic trinomial several methods are available; e. g., making the coefficient of x^2 a perfect square; "the guess and try" method; breaking b into two parts which are factors of ac. I have found this last to give the best results. If any subject in algebra needs the toning effects of generalized treatment it is factoring and it is this case and this treatment which gives that generalization.

You will note that I have included the Factor Theorem as one of the cases of factoring. In this connection I would suggest that we teach pupils to suspect exact divisors, that is factors, and not to suspect roots in the treatment of this case. Should the question arise, Why is it included in *first* year algebra? I shall reply, Yankee fashion, How can we afford to let a pupil leave high school without it?

Short and rapid methods of computation can often be shown by factoring formations; e. g.,

$$18\times 12 = (15+3)(15-3) = 216$$
$$78\times 99 = 78(100-1) = 7722$$
$$65\times 65 = 100(6^2)+20(30)+25 = 4225$$
$$83\times 87 = 100\cdot 8\cdot 9+3\cdot 7 = 7221$$
$$72\times 101 = 72(100+1) = 7272, \textit{etc.}$$

Thus, by algebra pupils will strengthen their power in arithmetic. They may even forget why their short methods are true but if they remember how to do them something has been gained.

Criticisms are always offered when graphs of equations are included in first year algebra. But these objections are less frequent and not so vigorous as formerly. In defense of the introduction of graphs, if defense is necessary, I would like to call your attention to the following suggestive statements: Mathematical reasoners have been divided by Poincaré into two distinct classes, the geometric or intuitional and the analytical or logical. Experiments conducted by F. C. Lewis show that those who are high in intuitional development are correspondingly low in logical work and that quite a percentage who are low in intuition are correspondingly high in logic. Pupils who are apt in the analysis of algebra may not need objective illustrations but those who are less analytical can be benefited by

graphic work. If we need objective teaching in developing arithmetic, why should we cease this practice? Shall we exclude graphic work because our first year pupils are skillful logicians? Which side of a girl's reasoning powers is most easily dealt with? They are very much in the intuitional classification. Why not appeal to this, since so many of our pupils are girls? Devices or diagrams, even though they may be the graphic representation of simultaneous equations, will help the pupils to understand much more than they would without them. And so we may go on and argue for first year graphic work, but it seems to me that the burden of proof should now be assumed by those who object to this introduction.

At the close of the first year's work I have added two new chapters. The first of these I have called "formulas." In this section, after the usual transformations have been reviewed, practical formulas should be given to the pupils. Formulas which need an involved technical explanation should not be used. But geometry, chemistry, physics and shop abound in usable material for this work. Pupils need to take this side of algebra with them when they leave the subject.

The last chapter of the course I have named "graphics." In this chapter I would have pupils understand the idea of function, to be able to arrange and compare numerical data and to be able to exhibit statistics in a telling manner. Curve plotting by the location of points by two coördinates (these coördinates may be rectangular, oblique, polar, vector and ordinate, etc.); representation by component parts (of circles and of rectangles); comparative representation depending upon proportional size of figures; temperature, time, cost, organization charts should be included in such work as I have in mind. How much of this work can be done should depend upon the interest of the pupils, but I suppose it will depend upon the attitude of the teacher.

I would like to propose here for your consideration what I think is a comprehensive plan for determining pupils' advancement. I have never completely tried out this plan because I have not had the authority to make the changes necessary. I give it here for what it is worth and if it is worth nothing it will readily be forgotten. I would determine a pupil's ability to advance solely upon his monthly averages. Into these monthly grades I would incorporate five elements, giving a total of twenty parts to each month's average. These five elements and the parts of each to be taken are as follows:

2 test marks (to count double)
1 mark for effort
1 mark for conduct
4 marks for home work
10 marks for recitation

Since we should, by this method, give different weights to the five elements, the separate marks should be made on the same scale. At the end of a five months' term the final grade is found by adding up the monthly averages. In marking the two tests I should suggest that one be given for accurate work (problems in this test to be marked 0 or 10) and the other for content (partial credits to be given). These tests should be supervised by the head of the department. In fact, I should have the complete authority of the department given to a head who would be responsible to the principal for the advancement of every individual pupil.

So I might go on and discuss other suggestive topics, such as recreations for an after school invitation class and their part in the school magazine; I might take up checks and their uses; I might discuss the qualifications of a good text. (But after all is said and done, all that is needed will be a list of exercises and a good teacher).

In closing I would say that we have too long made our first course in algebra fit the requirements of college entrance examinations. It is about time we fit our course to the pupils.

FUTURE VALUE OF LIBERTY BONDS.

There is every indication that Liberty Loan bonds, issued during the war, will greatly rise in value with the establishment of peace. In 1888 a $100 United States bond, bearing 4 per cent interest, sold in the open market for $130. In 1901 it brought more than $139. The most conservative will agree that Liberty bonds are sure to go above par in value, now that the Allies have brought the war to a victorious end.

The shrewd and unscrupulous, the birds of prey in finance, realize the worth of Liberty bonds, and are using every effort to secure them from those who are uninformed in financial matters. Their favorite method is to offer stock is wildcat companies—stock that is absolutely valueless—in exchange for Liberty bonds. Some of these get-rich-quick schemers offer to lend their prospective victims money wherewith to buy the goldbrick stock, taking Liberty bonds as security. This, of course, is only a thinly disguised attempt to obtain Liberty bonds for worthless stock.

The United States owns some 5,000,000 acres of oil lands and 53,000,000 acres of coal lands, the title to which belongs to the Federal Government. Since all owners of Liberty bonds are part owners of this Government, it would be palpably foolish of them to exchange their Liberty bonds for oil or coal stocks of doubtful value.

Before disposing of his bonds, the holder thereof would do well to consult a banker. Such consultation will not prosper the fake stock concerns, but it certainly will prosper the bond holder.

DO USE AND DISUSE MODIFY HEREDITY?

By Lyman C. Wooster,
State Normal School, Emporia, Kansas.

In considering this basic problem of evolution it is evidently necessary to study the dynamics of heredity. The fact that all forms of life inherit the tendencies and powers of their ancestors is unquestioned. Fish beget fish, birds beget birds and mammals beget mammals, each after its own kind. But how these tendencies and powers are transmitted through the egg, a one-celled body, is not so easy to comprehend.

The microscope shows that the egg consists of a cell wall, cytoplasm, concerned principally with nutrition, and nucleus, the part controlling cell division and bearing the hereditary qualities of the organism. All the parts named, the wall, the cytoplasm and the nucleus, are composed of protoplasm, the physical basis of life according to Huxley. Associated with the protoplasm of the egg are various hydrocarbons and carbohydrates which yield energy for the cell activities when oxidized, and certain other food materials not yet assimilated.

Naturally, the evolutionist is interested chiefly in protoplasm. The chemist tells him that it consists of an unknown number of kinds of protein, many of which are of unknown chemical composition. The biologist with the microscope can distinguish several varieties of protoplasm chiefly from the fact that they absorb various analine dyes in different degrees. One of these, which he has named chromatin, absorbs more of the dyestuff than any other and is the most active kind of protoplasm in the cell in cell division and hence is most interesting. The other kinds have special work to do in nutrition and in assisting the chromatin but are not thought to have much to do in heredity. The centrosomes and linin threads, however, merit watching. The centrosomes initiate cell division in most animal cells and in the cells of the lower plants. The linin threads manage the details of cell-division.

All the cells of all the tissues are derived from the fertilized egg cell through the process of cell division and growth of each cell from absorbed nourishment. All the daughter cells become specialized in a remarkable way as soma cells. Every cell of the body can do seven things, but the soma cells become specialized so they can do one of the seven things better than they can do the other six. The cells lining the alimentary canal are adept in the absorption of nourishment. The gland cells are wonderful

chemists. Other cells are chiefly interested in the excretion of waste. The egg and sperm cells continue the species. The cells of the special senses receive sensations. The muscle cells can contract so as to bring about movements of the parts of the body. The ganglion cells of the nervous system can do or not do many things for the good of the animal.

When the fertilized egg cell divides, each resulting cell has the contract for forming half of the body of all symmetrical animals, or, should the cells separate, the daughter cells may produce identical twins as in man. As the daughter cells increase in number by cell division and in size through the absorption of nourishment they assemble in tissues and organs, change their shape and structure—all as though they were obeying the word of command of some supervising architect. The inherited blue prints in these cases are followed with few mistakes and no cheating. The egg and sperm cells of adult animals have a specialization no more wonderful than that of the other soma cells. They have their special work to do and accomplish it in accordance with the inherited tendencies of their species.

The one question of absorbing interest to all students of life, whether plant or animal, is, Who is the supervising architect and how are his plans executed? Materialistic biologists have attempted to answer this question, but their biogens, biophors, determinants and energy reactions lie peacefully sleeping in the scrap heap of mere hypotheses.

It is the purpose of this paper to prove by inductive evidence that changes in the habits of animals (and plants as well) are registered slowly but surely in the body-building and body-using instincts of the succeeding generations.

In the Eocene period of the Tertiary era, as shown by their fossil skeletons, little horses grazed on the tender herbage of the swamps of western Kansas and Nebraska. These horses had four well developed toes on their fore feet and three toes on their hind feet, all being useful in supporting the animals in the bog-lands. The five-toed ancestors of these Eocene horses have not yet been discovered, but skeletons with the missing first digit will undoubtedly be unearthed in the near future.

As western Kansas and Nebraska became higher and drier with the upheaval of the Rocky Mountains, Eohippus depended more and more on speed to escape the wolves and fierce cats. In running, the little horses used the third digit chiefly, the second and fourth digits somewhat and the fifth digit not at all.

Slowly the third digits increased in size, and the fifth digits diminished till they became rudimentary and disappeared. It took one million years, according to Osborn, to lose the fifth digit through disuse. In the Miocene Tertiary all the fossil horse skeletons show but three toes. As the horses became larger and the plains higher and drier the horses used the third digit more exclusively. The third digits with their nails or hoofs grew in size with use and became the main and finally the only supports of the body. The second and fourth digits diminished in size with disuse as shown by a series of horse skeletons and are now rudimentary. These digits are represented in the modern horse by the so-called splint bones, rudiments beneath the skin of the metacarpal and metatarsal bones of these digits. Two additional million years were required to dispose of these side digits and make the American Quaternary horse an apparently one-toed animal.

The instinct in the horse for developing five digits on each leg is not entirely lost. According to Professor Wentworth of our Agricultural College, himself an authority on animal breeding, Doctor J. Cossar Ewart of Copenhagen says that three toes are found in the embryos of all horses at about the fifth or sixth week. In draft horse embryos vestiges of all five toes, according to Doctor Ewart, persist till the same period. Chestnuts and ergots on the legs of horses are usually regarded as representing the hoofs of the missing digits. The paleontologist can furnish dozens of examples showing the influence of environment in causing modification of parts through use or disuse. Osborn describes the Zeuglodon which became dog-like after having been a tree-inhabiting animal; later it took to the water and became a fish-like and later an eel-like mammal.

Whenever a need continues for many years, animals not overspecialized against it will modify their anatomy to meet the need even if it takes a million years or more to do so. Osborn says that all the radiating descendants of a group of hornless mammals may at different periods of geologic time give rise to similar horny outgrowths upon the forehead. The horny outgrowths were long needed for self defense, and in time they came. Natural selection helped after the horns appeared but did not start them or make them grow.

The examples are almost numberless wherein the needs of the working cells of the body are impressed on the chromatin of the egg and sperm cells and the fertilized egg cell has reacted

and made provision to meet the need in the course of millenniums of time, but how was the knowledge of the need transferred to the chromatin of the egg and sperm cells? The fact of the transference is demonstrated; the method of transfer is not understood with certainty.

Several ductless glands, such as the pituitary body at the base of the brain, the thyroids, parathyroids and thymus glands of the neck, and the suprarenals on the kidneys, all have a marked influence in stimulating or retarding the growth of various parts of the body through matter added to or subtracted from the blood. Various glands with ducts, such as the pancreas, liver and reproductive glands, share with the ductless glands the power to send accelerators or restrainers through the blood to various parts of the body. When the pituitary body is injured in a young mammal, such as a dog or sheep, the animal is dwarfed in size, has an excessive development of adipose tissue and has a delayed or imperfect sexual development. When the same gland is stimulated by disease, unusual growth of various parts of the body takes place. All have observed the remarkable results which have followed the castration of young males and similar modifications of the development of various parts of the body follow the extirpation of the other glands mentioned.

It is certain that the blood receives from the cells of these glands certain tiny bodies which produce the effects named. Some of these particles named antibodies confer immunity to germ diseases, others named hormones stimulate the growth of distant organs, and still others named chalones depress, retard or inhibit the activity of distant parts

Jordan says that the germ causing influenza is 1-2500 mm. by 1-5000 mm. in size; and the germ of infantile paralysis, measuring 1-5000 mm., is on the limits of microscopic vision. Beyond these, according to Jordan, are the ultramicroscopic bacteria, beyond the range of vision, some of which can pass through a porcelain filter.

If one-celled plants can be beyond the range of microscopic vision, is it any wonder that tiny messengers sent out by the chromatin of gland cells or any other cells of the body should escape observation? These messengers may be poured into the blood by any overworked cell and hastened in its swift current to auxiliary parts of the body for help in the shape of nourishment and oxygen. Some of these outshoots of chromatin may

find developing germ cells and modify to a slight degree the inheritance of the next and succeeding generations. This would be no more wonderful than the changes produced in distant parts of an organism by antibodies, hormones and chalones.

It is fortunate for each species of plant and animal that the changes in inheritance come slowly, keeping pace with the changes in the average environment, otherwise the plant or animal might not survive in its struggle for existence. In the geologic history of the earth many forms have failed to keep pace with their environment or have advanced too rapidly and in consequence have perished. Thousands of plants and animals that varied in the wrong direction, or too rapidly, or too slowly, were destroyed in the different periods of the earth's history, but other thousands of their relatives varied with their environments and therefore survived to continue earth's faunas and floras.

While the hormones (stimulators), chalones (retarders) and antibodies (immunizers) may not be alive, they originate in living cells and act on living cells, and hence owe their efficiency in guiding the development of plants and animals to protoplasm energized through life. It is life that is the variable and produces variations in organisms.

Osborn would evolve life from energy, but energy is invariable in its activities while life varies from day to day in each individual and from century to century in a series of individuals. Life, then, speeding with the blood in the tiny particles or sending the tiny particles, must be the real messenger from cell to cell. It alone has sufficient intelligence to thus provide for the inheritance of species instincts and their modifications through conscious use and disuse.

Darwin himself fully understood the limitations of his theory of natural and artificial selection. He knew that selection alone could not originate a part of a plant or animal or even modify it. Selection can merely sit in judgment on the work of conscious use or disuse and reject the individual when it is harmful to the species or accept the individual when it is helpful. The effects alone of conscious use and disuse of cells, tissues and organs can be inherited. Each tissue and organ had its beginning so long ago in time and so far down in the plant or animal kingdom that the cells were at first but slightly modified by life, and millions of years were required to bring the tissue or organ to perfection. Once completed, other millions of years are needed to lose the part, so slowly are species instincts changed by life through disuse.

THE PROJECT IN SCIENCE TEACHING.[1]

BY JOHN ALFORD STEVENSON, PH. D.,
University of Illinois.

The term *project* has made its appearance in educational literature rather frequently during the last few years, particularly in the fields of agriculture, general science, home economics, industrial education, and more recently in connection with the administration of the Smith-Hughes Act. The term *project* is used very frequently by science teachers, as a survey of the science literature and the subjects in their educational programs will show. Notwithstanding this apparent interest and enthusiasm for the *project method*, there seems to be no uniformity in the use of the term nor any special effort expended to arrive at a clear-cut definition or description of this latest arrival in educational terminology. Since there is no uniformity in the descriptions and definitions of the term *project* it seems worth while to determine whether the contribution it makes could be taken care of by other teaching units or concepts now in use, or to define the idea clearly so that it may take its proper place among other teaching units.

This paper will be devoted mainly to the investigation and solution of the following problems.

1. The determination of certain elements in a type of teaching situation which constitute the *project*. These will be treated as four pairs of contrasted aims in teaching.
2. An examination of the concepts now in use in science teaching for the purpose of estimating their availability for describing the teaching situation now called the *project*.
3. A statement and explanation of the term *project*.
4. A consideration of the *project* and its relation to problems, thinking, habit formation, action, and the curriculum.
5. A statement and discussion of the advantages and shortcomings of the *project method* in science teaching.

STANDARDS OF JUDGMENTS.

To determine the elements in a type of teaching situation which constitute a *project*, it is, of course, necessary to set up certain standards of judgment. These have to do, on the one hand, with learning and use of subject matter, and, on the other hand, with certain elements which will later be shown to be implied in the term *project*. These standards will be treated as four pairs of contrasted aims of types of learning, viz.:

1. Reasoning and the memory of information.
2. Conduct and information for its own sake.
3. Natural setting for learning and artificial setting for learning.
4. The priority of the problem or of principles.

---

[1]A paper read before the joint session of Science Teachers, Illinois High School Conference held at Urbana, November 21-23, 1918.

1. *Reasoning and the Memory of Information.* Two widely different methods of learning have been and are still used in educational practice. The one measures its success by the ability which the child has to reason; the other by the ability which the child has to appropriate the material outlined in the textbook and give it back when called for during the recitation. This latter method may be termed the acquisition of information by memory. The material in the lessons consists largely of dogmatic statements, and the mental activity demanded of the pupil is reduced largely to reproductive memory. The mental act demanded of the pupils in such exercises is not reasoning, but the mastery of statements outlined and organized by the author. This is clearly shown by the survey of textbooks used by children in the grades and high school. The questions at the close of the chapters in textbooks in physics, chemistry, general science, and other science texts may be answered, if the child remembers the statements which are given in the text. The activity, which the child uses, is confined largely to reproductive memory.

The recognition of the inadequacy of memorizing information is not recent, for seventy years ago, Horace Mann pointed out what earlier writers had noticed, viz., that verbal memory received too much attention.

A statement from Mann, quoted because of its humor, illustrates an extreme case of memoriter teaching.

"It recently happened, in a school within my own knowledge, that a class of small scholars in geography, on being examined respecting the natural divisions of the earth—its continents, oceans, islands, gulfs, etc., answered all the questions with admirable precision and promptness. They were then asked, by a visitor, some general questions about their lesson, amongst others, whether they had ever seen the earth about which they had been reading; and they unanimously declared in good faith that they never had.[2]

The defects of the memory exercises were noted early, and the correctives, which were suggested by Mann and others, grew into the concepts of the natural method, thought questions, and later into the more elaborate form now known as the problem method, sponsored particularly by John Dewey, Frank McMurry, and W. W. Charters.

The most important advantages claimed for the problem method are that it gives a better hold on subject matter and

[2]*Life and Works of Horace Mann*, Vol. 2, p. 68, "Lectures and Reports."

develops a technique of reasoning. It encourages and stirs up self-activity on the part of the child, so that he learns from his own experience.

2. *Conduct and Information for Its Own Sake.* The second pair of contrasted aims in types of learning, conduct and information for its own sake, will be considered. It is necessary to distinguish between the completion of an act (conduct) as over against reading about and learning the plan of an act (information).

Conduct as characterized by John Dewey is "a general term for the spirit and tenor of all the overt acts that constitute the behavior of an agent. As contrasted with the term *behavior*, the word *conduct* is usually limited to acts that have an end consciously in view and that are preceded by more or less deliberation—in short, to such acts as have moral quality, actual or potential."[3]

The implied question which it is necessary to consider is the character of the end of education. Is it the accumulation of information or the modification of conduct?

The answer which all teachers undoubtedly would give is that the modification of conduct is the true end of education. And yet in classroom practice, the mastery of information, and not its applications to problems of conduct, is all too frequently, made the important end of instruction.

It must be recognized that information does modify conduct but the modification is not automatic; it is to a very considerable degree both voluntary and conscious. It requires thought to apply information to conduct, and this application has such a subtle technic that instruction in the applications of information is necessary.

The act carried to completion guarantees that the solutions will be understood and will become the property of the individual who thus carries it out. Information will then be measured by the extent to which it can be made over into the experience of the individual using it to solve his problem.

3. *Natural Setting and Artificial Setting of Problems.* The question of whether the problem is in its natural or artificial setting constitutes the basis for the discussion of the third pair of contrasted aims of teaching. The question that must be answered in determining whether the setting is artificial or natural is this: Is the problem presented for solution by schoolroom

[3]Dewey, John, *Conduct;* Monroe, Paul, *Cyclopedia of Education*, 1911, Vol. 2, p. 175, Macmillan Company.

practice essentially different from that found in life outside the school? If the solution is carried on in the same way, then the problem has a natural setting even though it is being solved in the school.

The boy in an agricultural course, who determines to test his father's seed corn as a part of the school work, is carrying on the problem in about the same setting as if he were doing it at any other time. The girl in household science who becomes interested in the canning of fruit for the home as a part of the school work, is likewise carrying on the problem in its natural setting. The making of soap, the testing of baking powder, with the home interest in mind, are problems in their natural setting.

The criticism that the subject matter of the school is still largely isolated from the experiences outside the school is due largely to the fact that few provisions are made for attacking and solving problems in the school in their natural setting.

4. *The Priority of Principles or of Problems.* These rubrics indicate differences in the order in which principles and problems are presented. In the first, the study of principles precedes its applications to a problem; in the second case, the problem is staged for the learner and the principles are introduced when needed.

The foregoing method is commented upon by G. R. Twiss: "As finding the place of a new fact or phenomenon in the general system is always the final step for the scientist in the treatment of a problem, so it should be for the student in the science class. Accordingly, the logical position of a new fact should not be given by the teacher at the start, as so often it is, but should be found by the class after they have studied it.[4] And again, "This fundamental principle of science teaching—withhold theories until they are needed to explain the facts, and allow them to be used only as working hypotheses until the accumulated evidence forces conviction—is flagrantly violated in some of the most widely used texts in both chemistry and physics. In one physics text the wave theory of light comes almost at the beginning of the subject, and the molecular theory is introduced before the phenomena of heat are taken up. In several of the chemistries the authors take the shortest possible cut to the atomic theory. The result is muddy and vague talk by the pupils about what molecules and ether do, when plain statements of fact are required. It leads them inevitably toward a dogmatic, deductive attitude; and it fails to train them in distinguishing between

[4]Twiss, G. R., *Science Teaching*, pp. 77-78, 1917, Macmillan Company, Chicago.

fact and inference—an ability that is absolutely essential to any clear and scientific thinking."[5]

The advantages claimed for the priority of the problem as over against the priority of principles are the following:

1. The principles will be better understood when they are developed as the learner has need for them.
2. The principles learned in this way are learned in the same order that they were learned by the race. The formulation of the principles is the capstone of the observations. It does not come first.
3. There is more interest attached to the formulation of the principles.

The disadvantages claimed are that fewer principles may be given and a systematic outlook might be difficult to obtain. This question will be answered later when the implications of the *project method* are considered.

The Problem Restated.

Four pairs of standards have been mentioned: (1) information acquired by reasoning; (2) information for its own sake and information for use in modifying conduct; (3) learning in an artificial setting and learning in a natural setting; (4) and the study of principles before the problems in which they are useful as against the setting of problems with the introduction of principles as needed in their solution.

It is evident that there might be an important type of teaching situation in which the student would attack a problem in its natural setting, would obtain information by reasoning out his solution, would use this information in actually modifying his conduct, and would learn his facts and principles as the solution of his problem demanded. If so, there is a demand for a name for such a teaching situation provided no concept now in use denotes these elements, and provided the situation is of sufficient educational importance to warrant the invention of a new concept.

The question of whether the situation indicated above is of sufficient importance to warrant the invention of a new concept will be considered first.

That such teaching situations are numerous is clearly shown by the constant recurrence in several fields of instruction. Two fields may be mentioned here as illustrations. The situation in agriculture is stated by R. W. Stimson. "In the ordinary routine of the farm it may be that the boy is required to tend the poultry. During at least one year he should be given control of at least one pen of poultry, and facilities for feeding a balanced ration and trap nesting individual birds for comparison of productivity in laying."[6]

[5]Twiss, G. R., *Science Teaching*, p. 309, 1917, Macmillan Co., Chicago. (Quoted from Smith and Hall's *Teaching of Chemistry and Physics*, 1902, Chapter VI, Longmans, N. Y.)
[6]Stimson, R. W., *The Home-Project*, U. S. Bureau of Education, No. 579, p. 15, 1914.

In household science a student is required to assume responsibility for the purchase and preparation of the meals at home for a longer or shorter period with the understanding that they be well balanced.

These two problems are types of situations not at all uncommon in the agricultural and household science courses which involve the four standards of reasoning and information acquired as it is needed for use in carrying on a practical line of action in its natural setting.

Can the above teaching situations be taken care of by the accepted meanings of concepts now in use in science? If they can, there is no need of a new term in our educational terminology.

An Examination of Commonly Used Concepts.

The terms commonly used in accepted science texts are questions, problems, exercises, reviews, illustrations, applications, determinations, experiments, topics, and *practicums*. These terms are found with sufficient frequency to warrant the statement that they include the concepts now in common use in science teaching.

A critical examination of these concepts was made to see if any one is sufficiently inclusive and exclusive in its scope to provide for the situations cited in household science and agriculture. If all of the four desirable standards are not included or if any other than the four standards are included, it will be desirable to propose a new concept.

The method by which this examination of all the concepts was made will be illustrated by taking the problem and practicum, which approximate the concept *project*, to see whether they take care of the situations from agriculture and household science cited above. The definition of the term *problem* in its general use is given as stated by John Dewey. "Every conscious situation involving reflection presents a distinction between certain given conditions and something to be done with them; the possibility of a change. This contrast and connection of the given and the possible confers a certain problematic, uncertain aspect, upon those situations that evoke thought. There is an element, which may be slight or which may be intense, of perplexity, of difficulty, of confusion. The need of clearing up confusion, of straightening out an ambiguity, of overcoming an obstacle, of covering the gap between things as they

are and as they may be when transferred, is, in germ, a problem."[7]

In relation to the eight standards, the problem may lay stress on either the memory of information or reasoning. It usually emphasizes the intellectual phase of the solution rather than its carrying over to modify conduct, and it takes into account the natural setting but may, and often does, accept an artificial setting. As interpreted by the leading advocates of the problem method, however, it favors the priority of problem over the statement of principles. It does not, therefore, exclusively include all the standards which are necessary to take care of the type of situations as illustrated from agriculture and household science. The greatest shortcoming of the problem is that the solution is not necessarily carried over into action, but rather emphasizes intellectual activity. The actual carrying of the process over into action as in the preparation of the meals for a limited time and raising of the pen of poultry are not essential to the problem method. Unless the concept of problem as ordinarily used is modified, it will not take care of the items which our proposed concept embraces.

The term *practicum*, which represents one of the latest concepts in methods of teaching, is used particularly in agricultural education. It usually means the application of principles learned to the carrying out of an exercise which has economic value and which is of interest to the pupil. The definition given in the *Standard Dictionary* is "In some colleges and universities an academic exercise consisting of practical work as in the laboratory." Since in the term *practicum* principles are given priority over the problem the term cannot be used, without qualifying, to take care of the teaching situations cited above. The *practicum* makes no provision for arousing the interest of the pupil by placing it in a situation where principles must be developed as needed. In carrying out the situations in household science and agriculture by the *practicum* method it would be assumed that all the principles had been thoroughly mastered beforehand and that the exercises were merely to illustrate such principles.

An examination of all the concepts used in science shows that in their ordinary meaning they do not exclusively denote a method of teaching, involving reasoning primarily for the sake of modifying conduct in its natural setting and the introduction of principles as they are needed in the carrying out of an act. If any of the foregoing concepts or terms is used, some qualifying ad-

[7]Dewey, John, *Problem.* Monroe, Paul, *Cyclopedia of Education*, Macmillan Company, Chicago.

jective would have to be added to it, with attendant complication arising from confusion of meaning.

The Concept Project Proposed.

The concept which is proposed for the situations described in agriculture and household science is the project.

The justification for taking a term that has been in use for some time is that in general the aim of those who use it has been to take care of such situations as cited. The use of the term *project* seems to point to the movement for a term which will accommodate the above-mentioned situations. Again, since a few formal definitions have been proposed and since the limits of the *project*, as interpreted from the literature, have not been clearly drawn, it would seem advantageous to use it as our term and avoid the necessity of proposing another one. By so doing we should avoid the confusion which might come later in the use of the term *project* and the new concept proposed.

Definition of the Project.

The definition of the *project* which the writer proposes for substantiation is the following:

A project is a problematic act carried to completion in its natural setting.

In this definition note that (1) it implies an act carried to completion as over against the passive absorption of information; (2) it develops the problematic situation demanding reasoning rather than merely the memorizing of information; (3) it implies by emphasizing the problematic aspect, the priority of the problem over the statement of principles; and (4) it makes provision for the natural setting of problems as over against an artificial setting.

For the sake of clearness, a brief discussion of these particular phases of the definition will be given.

(1) The presentation of subject matter or the staging of a situation which results in activity, in carrying out the act to completion as over against the passive acceptance of information, is one of the most significant contributions of the project. For the term, act, or action, the definition of E. B. Titchener may be accepted. "In its most general meaning, an action is an organized movement; less generally, it is a movement of a locomotor organism. The characteristic feature of the action consciousness, as distinguished from the consciousness so far considered, is its predetermination in the sense of the idea of end."[8]

[8]Titchener, E. B., *A Text Book in Psychology*, pp. 448-449, Macmillan Company, Chicago.

In ordinary usage of the term, activity means the contraction and relaxation of muscles in physical activity. For educational purposes the meaning should be broadened to include the situations defined by Dewey "as a series of changes definitely adapted to accomplishing an end. Hence it is opposed to restless and random changes, as well as to mere quiescence and passive absorption. Dictated exercises . . . . . when not accompanied by any sense of a result to which they naturally contribute, are not activity in its genuine, or intellectual, significance; neither is undirected overflow of motor impulse."[9]

There are many different kinds of activity, intellectual, social, religious, and physical. The *project* does not limit itself to physical activities alone but makes provision for these other acts, provided the individual takes a part in the purpose, choice, and reflection of the directed action. Thus "physical activity when not accompanied by any sense of the result" is not considered activity, but intellectual activity when accompanied by a sense of result is considered an activity in an educational sense.

The expression, *problematic act*, has been formulated and used in the definition of *project* for the distinct purpose of emphasizing not only the act but also the problematic aspect of the act.

(2) It is essential that the *project* be understood to include a problem, otherwise it could not be differentiated from habits and reflexes such as digestion, respiration, or from knitting and dishwashing after they have become habitual. The *project* may include habits and reflexes, provided in addition there is involved a problem, a situation demanding reasoning for a solution.

(3) The problem aspect of the *project* not only involves reasoning but contains a distinct implication of priority of the problem situation over the statement of principles. The learner in the *project method* is brought face to face with the difficulty, and in the process of dissolving this difficulty or arriving at a solution, principles are developed as needed. The skill in teaching is brought into play just here—in staging situations which present difficulties and arouse in the mind of the learner a need for solutions.

(4) The implication of the term, *natural setting*, has been discussed in the beginning of this paper and it is unnecessary here to go into detail other than to state that the project provides for the natural setting of situations, which means that the situa-

[9]Dewey, John, *Activity;* Monroe, Paul, *Cyclopedia of Education*, Macmillan Company, Chicago.

tions undertaken in school are not essentially different because they are problems taken up in the school from what they would be were they to come up in life outside the school.

The situations which were proposed in connection with the study of household science and agriculture are adequately taken care of by the concept *project* as here defined and described.

The boy who controlled at least one pen of poultry, with facilities for feeding a balanced ration and trap nesting individual birds for comparison of productivity in laying, would be brought into a situation which demands reasoning. The memory of information would not be sufficient to carry on this problem, for the conditions as they change daily, demand reasoning. The results of his investigation and the principles which would be evolved as needed would result in the completion of the act in its natural setting. If the boy had become interested in the *project*, had started it, but after a few days or weeks had stopped, no results of any consequence would have resulted and it would have illustrated a situation, arising in its natural setting, but not carried to completion. This could be designated as an incomplete *project*.

The Need of the Concept Project for Certain Types of Teaching Situations.

Situations, such as the foregoing, have been recognized for a long time by educators as a type of educational problem which is worthy of solution, even though it has seemed difficult to devise a teaching unit which would handle such a situation. The recognition of the need for such a concept has led to discussion of the *project* with concurrent definitions which vary more or less in inclusiveness, yet which indicate a search for a concept such as proposed.

Definitions of Project Proposed by Teachers of Science.

The *project* has been developed and used rather extensively by teachers of science, yet very few definitions have appeared, and even these probably could better be termed characterizations.

The most comprehensive characterization has been given by C. R. Mann:

"(1) A desire to understand the meaning and use of some fact, phenomenon, or experience. This leads to questions and problems. (2) A conviction that it is worth while and possible to secure an understanding of the thing in question. This causes one to work with an impelling interest. (3) The gathering

from experience, books, and experiments of the needed information, and the application of this information to answer the question in hand."[10]

A few citations from the writings of J. F. Woodhull will give his views of the *project method* in science.

"The purpose of science teaching in all grades of schools is not chiefly to impart knowledge of subject matter but to train persons in the method of the masters, which is invariably the project method. This is the method used by intelligent men in achieving their ends, in school or out."[11] In commenting on the method of the masters this reference will be explanatory: "The real way to learn fundamental principles is to attack those problems of which life is full for each individual, not through the preparatory fallacy called the scientific method, but by a 'forked road situation.' The school should prepare pupils to walk alone by attacking real problems as Archimedes, Galileo, Davy, Faraday, Pasteur, Tyndall, and all the rest did. Most of us know, if we would think back over our experiences, that we never really learn these so-called fundamental principles until they come to us as an interpretation of some of our life's problems."[12]

Woodhull indicates that the *project method* is nothing more nor less than the method of the scientist adapted to children. In order to get a more accurate notion of Woodhull's conception of the *project* it is necessary to determine just what is the method of the scientist. Morris Meister of Columbia University gives the following analysis of the scientist at work.

"(1) That he begins in a state of perplexity.

"(2) That he works with an intense enthusiasm because this perplexity is the result of a real, pressing, vital difficulty.

"(3) Once the difficulty is clearly defined his enthusiasm carries him to a solution by a process which is automatic but which can be described as:

"(a) A process of rapid suggestion, supposition, guess, hypothesis, or theory—pending further evidence.

"(b) 'Reasoning out' the implications of each suggestion.

"(c) Deliberately and cleverly arranging conditions in accord with the requirements of any of the suggestions to see what results occur and to weed out the false suggestions."[13]

---

[10]Woodhull, John F., "The Aims and Methods of Science Teaching," *General Science Quarterly*, Vol. 2, pp. 249-250, November, 1917. (Quotation of Mann cited).
[11]Woodhull, John F., "The Aims and Methods of Science Teaching," *General Science Quarterly*, Vol. 2, p. 249, November, 1917.
[12]Woodhull, John F., "Science Teaching by Projects," SCHOOL SCIENCE AND MATHEMATICS, Vol. 15, p. 229, 1915.
[13]Meister, Morris, "The Method of Scientists," SCHOOL SCIENCE AND MATHEMATICS, Vol. 18, p. 743.

Another statement by Woodhull is pertinent to this discussion:

"*A project*, or *problem*, differs from and is superior to a topic in that (1) a *project* originates in some question, and not in such a logical sequence of ideas as may be found in codified subject matter. In teaching from the so-called 'logical' texts one wrongly attempts to induce pupils to accept topics as their own *projects*. Logical organization of such material as functions in life will be the final result of a protracted study of *projects*. (2) The *project* involves the active and motivated participation of the pupil in carrying it out. It does not, therefore, like the topic, lend itself to didactic, formal treatment in which the teacher does all the thinking and the pupil passively absorbs. (3) *Projects* furnish a basis for the selection of facts according to value or significance; topics furnish no such basis for selection. (4) The *project* seldom ends in a complete, final, or absolutely finished conclusion."[14]

Again, J. A. Drushel, science teacher in Harris Teachers College, St. Louis, Missouri, proposes this definition: "A project is a concrete problem outlined sufficiently fully and clearly to enable the student, for whom it is designed, to carry it out."[15]

J. A. Randall, Department of Physics, Pratt Institute, Brooklyn, New York, defined a school *project* as "a problem the solution of which results in the projection of some object or knowledge of such value to the worker as to make the labor involved seem to him worth while."[16]

The definitions proposed in the field of science agree in that the *project* involves a problematic situation; in fact, Woodhull does not differentiate between the *project* and the *problem*, but Randall and Woodhull alone lay emphasis on carrying the act to completion. Randall makes no provision for the natural setting of the problem. The situation outlined by Mann and Woodhull may be properly classed as a multi-problem, by Drushel an application, while Randall's definition covers most of the elements which have been considered essential to the *project*, with the exception that the natural setting for the problem is not specifically indicated.

Implications of the Project.

The definition of the *project* takes into account the natural setting of the problematic act, which means that it has significance for the learner. The natural setting provides a strong motive—testing seed corn for the father is more interesting than

[14]Woodhull, John F., "The Aims and Methods of Science Teaching," *General Science Quarterly*, Vol. 2, p. 2, November, 1917..

[15]Drushel, J. A., Definition sent to writer by Superintendent John W. Withers, St. Louis, Missouri, March 23, 1918.

[16]Randall, J. A., "Project Teaching," *N. E. A. Report*, p. 1010, 1915.

making laboratory tests of one or two ears of corn. All *projects* may not be interesting to any one student, but interest in the projects selected by the pupil is likely to be very high. When a *project* is interesting it is very interesting. The *project* creates interest of a deep-seated sort because the interest comes from associative connections of many sources. The *project* offers many more reservoirs from which interest may be drawn.

If the *project* is to be made the basis for the curriculum it is necessary to decide what principles should be mastered by the students and then select *projects* or groups of *projects* from which the students may select. The *projects* selected by the pupils will be such that all the facts, principles, and processes will be covered which ordinarily are covered in the logical or systematic presentation.

After the facts, principles, and processes have been covered by the *project method* in class, enough time should be left in the course so that the subject matter may be systematized. First, the *project* is used for the approach to all parts of the subject, and then a systematizing study of the field follows as an extended summary.

The shortcomings of the *project method* are in not making adequate provision for habits and skills and for giving a systematic or logical view of the subject. A methodology which makes no provision for these other than in a purely incidental way, is seriously defective and may greatly make its theory subject to the criticism that it is encouraging "soft pedagogy."

The use of the *project* in science teaching is not always in good repute, not due to any inherent fault of the method, but due rather to the fact that the method is rarely carried to completion. As Bobbitt suggests, "It is by far the most complicated method and differs most from familiar traditional ones. It is not, therefore, surprising that teachers often develop an incomplete and ineffective form of the method. Whenever a training task involves practical performance, this is so visible, tangible, and solid sense that it often comes to be conceived as being the whole thing. The teacher attempts to get the pupils in the most economical and expeditious way to perform the practical actions by way of securing the results. The teachers, therefore, often do the thinking, draw up the plans, and prescribe procedure for the students."[17] Such a procedure, of course, is not the spirit of the project method and rightfully deserves such characterization as

[17]Bobbitt, F., *The Curriculum*, pp. 31-32, 1918, Houghton, Mifflin and Company, Chicago.

a "hodgepodge" science, "soft pedagogy," an "unorganized mass," "a device for getting hold of deficient students and keeping them from making trouble or from leaving school."

The *project method* rightly carried on develops great interest, gives training in carrying acts to completion, and provides adequate opportunity for directing thinking and reasoning. Its shortcomings are in providing for habit formation and a systematic view of subject matter.

RECONSTRUCTION AFTER THE WORLD WAR—AN OMNINATIONAL CONFEDERATION.

Practical schemes for world reorganization have thus far been conspicuous by their absence, so far as the press is concerned. A scheme which seems to have much to commend it to the attention of intelligent readers in all parts of this war-shattered world, is given to the public by the great geologist, Professor T. C. Chamberlin of the University of Chicago.

Professor Chamberlin, with his usual scientific foresight, more than a year ago recognized the need of a systematic planning for the future, that we might not be as unprepared for peace when it should come as we were for the war. His idea was that data in scientific, historic, economic, and all other lines having a bearing on right and stable readjustment of international affairs should be patiently gathered, sorted, and analyzed, for a long period before the end of the war, and from this fund of well-assorted and digested information various alternative plans should be formulated in convenient shape for ready consideration and comparison at the peace conference. However, when the daily war news of the past summer gave indication that time for such deliberate and laborious preparation for peace would not be available, Professor Chamberlin, realizing that some shorter process must be adopted, decided to select and formulate, from the various plans he had himself been considering, the one that seemed to him most hopeful in the light of all the information he could glean from the press, from correspondence and interviews with men in close touch with the numerous questions that must be dealt with, and from his own broad experience and knowledge of world problems. He showed a preliminary draft of this project to certain personal friends among scientists, economists, and statesmen, and finding it received not only with favor but with enthusiasm, as an exceptionally practical solution of a most intricate and almost hopelessly involved problem, he is now giving the reading public a chance to consider its workableness.

Unique features of this plan are:

An Omninational Confederation based on a world business organization rather than upon political governmental lines—each nation to have voting power and responsibilities in proportion to its share in international commerce.

A number of omninational highways forming a gridiron of commercial worldways across Europe and Asia Minor, to be policed and controlled by the Omninational Confederation so as to afford trade outlets and inlets for the inland countries, for the free use of all nations, on the analogy of the common use of the seas for all nations alike.

Everybody expects some sort of permanent League of Nations to result from the forthcoming Peace Conference, but Professor Chamberlin's idea contemplates two great bodies—one, the present war-born league of

Allied nations, to settle the war, and the other a permanent Omninational Confederation, to establish and maintain peace, the work of the former to overlap that of the latter and continue simultaneously with it for as long a time as proves needful.

In the discussion and explanation of his scheme, Professor Chamberlin's paper which will appear in the *Journal of Geology* November-December, 1918, develops the following points:

The peculiar fitness of the existing warborn League of Nations for the settlement of the war issues.

The punitive war function versus the requisite impartial peace function.

The settlement of immediate war issues, a necessary step toward new organization.

A period of national reconstruction necessary.

A further test of the principle of allocation of resources.

The new nationalities to be considered.

The basis of the new organization: (*a*) Fair opportunities for commercial intercourse between all peoples under such reasonable economic regulations as they themselves may impose. (*b*) Protection and regulation of international intercourse by an omninational body representative of all peoples in proportion to their participation in international commerce.

Here he discusses the high seas, certain straits and lesser waterways, and railroads, roadways, and other thoroughfares in specified locations on land, as worldways for universal commercial intercourse—a very critical feature in providing against a frequent source of past wars.

Preeminent domain of these common highways to be assumed by the Omninational Confederation. These worldways as barriers against aggression. Their relations to national boundaries. The proposed gridiron of omninational highways. The highway problem of Asia Minor. Relations of omninational highways to other transportation lines.

The bearing of the proposed measures on the thirst for national possessions.

The province assigned the Omninational Confederation.

The Omninational Confederation is not proposed as a mode of political or social government (which would be unwise because of the great diversities in races, religions, and customs of the different nations), but as a cooperative economic agency controlling the essence of international affairs. Cogent reasons for adopting this basis are:

1. The commerce of the world is a concrete, measurable activity.
2. It offers a workable basis of control and administration.
3. Inasmuch as each nation's commerce is definite and registrable, a graded participation in control and administration is entirely practicable.
4. Such control and administration is in its nature both just and conducive to the common advantage.

The functions of the Confederation: It shall take entire control of policing the high seas and other waterways and regulating international commerce upon them as may be necessary and equitable, and shall exercise the right of preeminent domain on the land so far as is necessary to provide, maintain, and operate omninational commerical highways.

The ruling bodies of the Omninational Confederation.

The permanent seat of the Confederation—Constantinople, because

1. It has been the center of chronic difficulties for nearly five centuries.
2. The possession of this strategic situation by all nations jointly would settle one of the most serious problems of the Near East.
3. The nationalities that most need to be led into the newer and broad-

er national spirit would be nearest the new seat of influence.

4. The Confederation would be near the junction of three grand divisions—a convenient location for future expansion of its work.

The naval and military forces of the Confederation.

Monopoly of the manufacture of arms and explosives of all kinds.

The financing of the Confederation.—[*University of Chicago Press.*

HOW THE DIVISION OF AGRICULTURAL INSTRUCTION, STATES RELATIONS SERVICE, U. S. DEPARTMENT OF AGRICULTURE, MAY HELP THE TEACHER OF AGRICULTURE.

The chief function of the work of this division is to furnish agricultural information as to subject matter, method of instruction, and plans and courses of study for administering the same. This is done mainly along the following lines:

Cooperative work with the Federal Board for Vocational Education and the U. S. Bureau of Education in a series of investigations.

Cooperation with the states in preparing courses of study in agriculture for elementary schools.

Cooperation with the teacher training forces by helpful publications, visits, lectures, conferences, loan of illustrated lectures, and correspondence.

Cooperation direct with the teacher in the field by furnishing lantern slide lecture sets, information concerning source of helpful materials and the utilization of community surveys, instruction connected with home project work, use of publications, and solution of local problems.

This division will furnish free of charge to any teacher requesting the same the following material:

1. Classified lists of Department publications arranged for the use of teachers (all the publications of the U. S. Department of Agriculture arranged and classified under the various divisions of agricultural instruction.)
2. Lists of agricultural texts and reference books classified for secondary schools.
3. Classified lists of texts and reference books on elementary agriculture and nature study.
4. Lists of teachers' professional books classified.
5. A list of best books on rural life.
6. A suggested library for home makers.
7. List of sources of pictures useful in teaching elementary agriculture and nature study.
8. Sources of projection apparatus, slides, etc.
9. List of dealers in agricultural and other scientific apparatus and supplies.
10. List of sources of maps, charts and models.
11. List of exhibits furnished to schools.
12. A series of documents on phases of secondary instruction in agriculture.
13. Leaflets on how teachers may use certain Farmers' Bulletins.
14. Lantern slide lecture sets loaned free by this division (a series of eighteen lectures on various topics in agriculture, and methods and plans for teaching same).
15. A suggested library plan for arranging, classifying, and using an agricultural library in a school or in a home.

Address: Alvin Dille, In Charge of Agricultural Instruction, States Relations Service, U. S. Department of Agriculture, Washington, D. C

THE NEW PHYSICS.

By C. L. Vestal,
Carl Schurz High School, Chicago.

In the next ten years we are likely to see considerable changes in our social structure. We cannot, we should not, hope that education will escape these changes. Education is the foundation of successful democracy. It is essential, therefore, that it be revised from time to time to fit democracy's changing needs. Educational procedure, as it stands today, is partially out of touch with the lives of the people who support it. The coming changes, then, will be in the nature of establishing the desired contact.

The subject of physics has to bear its share of this charge of remoteness from reality. It is less open to this charge than most other subjects because of the nature of its matter, which the pupil sees around him every day. So great is this inherent vitality that its revivification should not be difficult. The fault is not in the fundamentals. These are eternal truth. It lies rather in the assumed aims of its exponents, and their consequent aloof attitude toward the contact of their science with the popular life. This attitude has of necessity used corresponding methods of presentation, and hence the whole subject has not been able to escape the charge of social irrelevance. On the whole, we have been, and still are, administering a system handed down to us, rather than studying actual needs and then constructing a procedure to fit them. We cannot mold these needs of the people to fit a preconceived system. They are molded by forces of which our own subject is only one of very many. In a democracy education is a tool, a means to national happiness. When changes are necessary it is the means, not the end, which must do the adapting. I am convinced that we can maintain the value of our subject in the eyes of the people only by bringing it into intimate contact with the lives of our pupils, and their parents as well. To this end we must adopt more fully a method which might be called associative teaching.

I do not mean to give the impression that all of our physics teaching is remote from life. Much of it even now is presented in terms of the pupil's daily observation and experience. Better still, that much is growing into more. But that a very large percentage of it is still open to the charge of aloofness we can prove to ourselves by looking over the catalogs of physical apparatus. How little of that represents means of adapting these

world energies to the uses of man! That, to be sure, is not the maker's fault. He has made what teachers demanded, and teachers demanded what their scholastic training, from the point of view of pure science, taught them to demand—mostly highly specialized pieces, designed to bring out an abstract fact or law by itself. It seems to me that, for the high school pupil, this is not good pedagogy. It has its place, not as the center of the study, but as an accessory in the study of the real thing.

Of course it demonstrates a truth, and no truth is absolutely unrelated to life, but if those to whom we are teaching it do not see any such relation, the isolation exists in effect. For popular science—and I use that phrase in the full consciousness of its possible odium in the eyes of teachers trained as we have been—must not emphasize the research point of view. The implication of this statement is that high school science should be popular science. I am convinced that this is true, in the larger sense of the term, being careful to exclude that demagoguery which exists among "scientific" writers no less than among "political" writers. A definite attempt to obtain popular appreciation is not necessarily pernicious. In fact it is the final touchstone to which a democracy must inevitably submit all its varied activities. True popular science is not necessarily superficial. That is a matter of teaching. It will not even be spectacular. It is a method of making and maintaining this appeal that I seek and urge others to seek. However applied, such a method must be an associative one, a method which causes the pupil to naturally associate in his mind the matter of class discussion and experiment with its uses for human happiness and progress. So I have used the phrase, "associative teaching."

To discuss and illustrate the matter fully would require a volume—which, when written, would be highly speculative, because the technique is not yet by any means worked out. It only has a very hopeful beginning. Not the least of its merits is that it requires us to subject our methods to the test of experiment. I am willing to suggest that, for one thing, we will find it to mean something like this: Instead of using highly specialized apparatus as the center of attention, let us take, so far as possible, the actual pieces in which the laws are made use of practically, and demonstrate and study from them. If the things themselves are not available—and in many cases they never can be—let us imitate them as closely as possible, by working models, or

imitative arrangements of apparatus at hand. The place of the specialized demonstration is to clear up some question growing out of the study of the real thing. Let the derivation of the law follow instead of lead some understanding of its applications.

Permit me space for a few illustrations. Before beginning any topic, let us ask ourselves: What are my pupils' association with this topic? This is not a difficult question to answer, since the teacher usually lives in much the same environment as do his pupils. Then let us begin our discussion with the devices that use the laws we want to impress. Take for example the topic under the, to the pupil, formidable title, "Statics of Liquids." What is the pupil's association with that? Well, his most familiar one is not statics at all, but dynamics, in the form of the flow of water through a pipe, the significant thing being the sometimes annoying drop in pressure. Great numbers of pupils have noticed that when everybody in the block wants to sprinkle lawns at once on hot evenings, they can hardly get water from the faucets in the house. To explain and test this I would suggest using a run of small water pipe the length of the laboratory, with dial pressure gauges at intervals of six feet, and faucets similarly spaced, so that the effect of flow on pressure distribution can be observed, and measured, if a water meter is available. I have to confess that I have never been so fortunate as to be able to try this. Another association is the pressure produced by a standpipe. Let us investigate this by elevating a small tank above the lecture table to a height of eight feet or more, and connect it with the sink below by a vertical water pipe carrying three dial pressure gauges at intervals. Accurate gauges reading to but five pounds can be had reasonably. We would thus obtain directly the relation between depth and pressure.

As a means of accomplishing the study, let us give the pupils a list of detailed and searching questions, covering both the details of operation and the governing principles. Let these questions be of a grade of which most of the pupils can answer eighty-five per cent to ninety per cent in a reasonable time. The rest of the questions might well be of such a nature that only a few of the more brilliant ones could answer them. This gives the bright ones an opportunity to extend themselves, and so keeps up their interest. Do not undertake to derive any laws until the construction and operation have been well studied. Then call the class together, taking it part at a time, if neces-

sary, and use the questions given as a basis for recitation, and the tying together of related parts. Finally derive, state, and amplify the laws. Do not require the pupil to make a written report on everything thus studied. When a report is demanded, however, see that it is very carefully done, with a line drawing of the device studied; having all parts properly named, a statement of the law or laws upon which the operation depends, and a clear explanation of how this law is involved.

Space forbids me to carry these illustrations further. Once started along this line, your own imaginations can suggest plenty of others. I have little doubt but that a list of a hundred such studies or "experiments" could be suggested, very few of which have been actually tried to find out how they will work, if at all. I wish now to consider some of the changes involved in the adoption of this associative method.

In the first place there is the matter of equipment. Our laboratories are, for the most part, equipped for the old formal, rigid methods. They would have to be re-equipped. However, this is not quite so forbidding as it sounds. It would have to be done gradually. Let us replace no more formalism with itself, but year by year, as we can obtain the money, let us invest it in the new method equipment. In fact, we would have to do it gradually even if we had unlimited funds, because it is only gradually that we can find out just what we do need. Let the arrival of the new be evolution instead of revolution. The latter always arouses fight.

Secondly, it means a change in our teaching method in the laboratory. Instead of the alleged individual experiment, we must come to some form of the group experiment. Here, too, the change is more striking in statement than in reality. With four pupils at a table, as in many laboratories, the work is a group affair anyway, led by one pupil who knows what to do, while the rest look on and take down data. Since tables are close together, the group often includes more than those at the one table. I am not sure that this is reprehensible. A great deal of the time and for all but a few of the pupils the physics is buried in manipulation of apparatus. No doubt it is true that if we could have each pupil work entirely alone he would get the matter more thoroughly than he ever really does, but with classes averaging twenty-five to thirty pupils this is impossible.

Again, adoption of the new idea will mean a much less rigid differentiation between "laboratory" and "class." The labora-

tory should always be large enough to contain seats for the class. Then the instructor may call the whole class, or any part of it, together at any time for explanation or study, thereby striking while the iron is hot. The class should be in the laboratory most of the time, the teacher doing his work by being always among the pupils, ready to apply real teaching on the spot when it is needed. The pupils will be using the study questions given them when the device was taken up. The total class time should not be less than seven periods per week. Ten would be better. Usually not more than three of these should be spent in formal recitation, although that could be determined only by the individual class in hand. It should not be a hard and fast matter. Thus there would be given some real significance to the phrase, "teaching by the laboratory method." It should be added that the new physics would not confine its laboratory to the four walls of the room which goes by that name. The properly designed modern school building, a building whose guiding idea came from an educator with vision and imagination, would first of all be regarded, not merely as a shelter and accommodation, but as an educational plant from top to bottom. The heating, piping, and wiring of the whole building would be so laid out as to allow frequent and convenient places of access to these services for purposes of testing by pupils, properly supervised. Let the water pipes and gas pipes carry accurate and sensitive meters, not only where they enter the building, but on other floors and where they enter the laboratory and lecture room. There should also be easily accessible pressure gauges on the water and steam pipes at different levels and distances. If there are steam engines, let them be available for pupil study. Let the electric circuits be equipped with ammeters at the cut-out boxes or distribution boards on the different floors, and with ammeters and wattmeters and watt-hour meters where they enter the laboratory. Practically all of these pupil observations can be made without in any way interfering with the service itself. A school is not truly such unless the whole of it is at the disposal of its own educational aims.

Let us occasionally make visits to manufacturing plants, attendance not compulsory, but only for such pupils as really wish to go. Let the pupils be given points to observe before going. Let them also be given questions about devices or pieces of machinery which they frequently see. Let them be encouraged, and even required, to bring in questions from home.

Every progressive physics teacher should prepare himself to be a kind of consulting household engineer. Let him be able to explain the probable troubles of a heating or plumbing system or a lighting or bell circuit. Outside of its own intrinsic utilitarian value, this will give the children a better appreciation of their homes and accessories for comfortable living. It will cause them to associate home and school more closely than is usually done. It will heighten the parents' respect for both school and teacher. Our high school youngsters are too apt to feel that the homely things, when mentioned in the classroom, are subjects for more or less contemptuous laughter. We can do a great deal to eliminate this feeling, and substitute for it a respect for the art of decent, rational living.

Another change demanded will be the character of the texts. With one or two exceptions, these are written from the formalistic, remote, research point of view. We have got to get more into the adolescent point of view, and renew our youth. Of course our enthusiasm must be tempered by experience and organized by knowledge, but it need not be killed by them. Let us do most of our quantitative work in written problems, basing them, so far as possible, on applications the pupils have seen. Let us undertake accurate experimental demonstration only where there is no reasonable doubt but what we can prove what we set out to prove. Too often we are condemned to explain "why it didn't work." The usual methods of demonstrating Boyle's Law, Pascal's Law, and Charles' Law are cases in point. The high school physics laboratory is no place for the methods of the Bureau of Standards. We have neither its equipment nor its leisure, and should not aim at its results. The pure laws are seldom used unadulterated, anyway. They are merely made the basis for design. In the high school laboratory let us lay more emphasis upon the "how" than upon the "how much."

No doubt this idea of physics teaching will meet with some strenuous objections, and equally strenuous misunderstandings. The same word does not mean exactly the same thing to everybody. One will be cost of equipment. But, as I have already said, this can be brought about gradually. It is my opinion that Boards of Education will, on the whole, be favorable to the idea. They are not academic-minded, and they are more likely to take the popular point of view.

Another objection will be the extra work it may make the

teacher. That it will require him to be more alert than he usually is I think probable, but this should make for the good of the service. It will also take more outside time for preparation until a successful attack is worked out for each particular "study." Whether it will make him work harder in the class-room will depend a good deal upon his own organizing ability. To follow this course no text has yet been written, and we must make our own as we go along. I believe the real teacher will find in this condition the freedom he has so long desired.

Another objection is the inflexibility of our laboratories themselves. They have mostly been made with the idea that only little toys would ever be handled there. Tables are far too close together, and are seldom the correct height. There are no provisions for hanging weights from the walls or ceiling. The table tops are such that nothing must be screwed to them. There is seldom any small workshop attached, for the purpose of making small pieces and minor repairs. There is no allowance for mounting certain pieces permanently. These inherent defects of the present laboratories can only be overcome by more or less effective makeshifts. New ones should be planned in the light of the new ideas.

A serious objection will come from our classically trained teachers, who will see in this idea a lowering of standards. They will tell you that the main thing in a course is discipline, that it must be "stiff" or it is not worth much. Of course they will admit that the subject matter ought to have some value and interest of its own, but that this is secondary.

The advocates of the new physics must plead guilty to the charge of aiming at greater interest in the course. They are not ready to admit, however, that adding interest reduces disciplinary possibilities. It is probably true that the pupil will more easily master what is interesting than what is dead, but we would contend that, while difficulty is one element of discipline, it is not the only one. The subject matter of a living physics can be made just as severe as required. Fundamentally, discipline is requiring the pupil to adapt himself to the wholesome and worthy in life, by which it would hardly seem that the things remote from life are the most effective means thereto. The new physics does not propose to relax discipline. It merely proposes to add meaning to it. Formal discipline belongs to the days when it was thought to consist mainly in repression. Does the boy like a thing? Therefore it is not good for him. Repression has its

place, but only in connection with stimulation. It is the negative aspect of discipline which has hitherto been overemphasized in our curriculum. In its own field the new physics hopes to supplement this with stimulation.

We shall probably also hear the objection that this idea means the lowering of physics to a merely utilitarian purpose, without the saving grace of having it aim definitely at any trade or profession. I do not believe this charge has any justification. We have all always taken for granted that physics was the foundation of certain trade and professional courses, but we never regarded that as its sole aim. As a matter of fact the mere informational content of physics, even when taught by the associative method, will not impress the pupil very greatly. For technical information to be of definite value its recipient must be an actual practitioner of the vocation upon which it bears. He must be brought into daily contact with examples of the information he has acquired. He must use this information, or it will not become a utilitarian part of him. This the high school children are not doing, except in an extremely limited way. Certain household information should be of use in their daily lives, and the imparting of this is eminently worth while, because it tends to raise the plane of living. It is not a sordid matter. Even after they leave school, most of the pupils will have little direct use for this information. By this time it will have long been forgotten, and will have to be relearned when needed. It is our hope, however, that the first learning will greatly shorten apprenticeship, but it will not take the place of it, even in the vocation of teaching. The implied charge of sordidness falls down.

Our real aim is as high as our ideals for better citizens. We wish to adopt this method purely on pedagogical grounds. The fundamental thing in all activity is life. It is life that we want to make our subject take hold of, to help our pupils live highly and happily. If our teaching remains remote from their lives it can have little influence in them, and is therefore and to that extent shorn of social justification.

Finally, we teachers need this change for our own sakes. The life has largely gone out of the formal, scholastic methods. Using them, we are isolated and irrelevant, without a background of social worth. They have given us a tendency to withdraw from life, and cloister ourselves away from its rude barbarisms in the little hermit world of our pale intellectual enjoyments. We have thus gradually come to fear and shrink from

anything robust. In our contact with our pupils we are still largely a hazy reflection of life as it is and as they will have to live it. We are somewhat in the position of the patent medicine manufacturer, who classifies all ills under general debility, and then guarantees his decoction to cure that—or to keep it so drunk that the patient will remain unconscious of it. We have been press agents and salesmen of a scholastic patent medicine. We have never really made a diagnosis to see just what training was needed. We are trying to fit the pupil to the system rather than the system to the pupil. We have got to make a more rational combination of these two phases of education. Do we not need, more than anything else, to forget our texts and manuals and study seriously the ways in which our subject touches the lives of the pupils and their parents, and then make that subject a part of their lives, a part which fits, not a patch stuck on in spite of blind protest? Let us become in some part ourselves experimenters in matter and method, instead of asking our pupils to plow and replow partially barren ground. Lacking this, our imaginations gradually become atrophied and our enthusiasms evaporate, or are reserved for outside interests which have life. This mechanical, perfunctory attitude has a reaction on the pupils. Our souls are not in it. They have become dessicated by disuse, and each day the class comes reluctantly, remains restively, and rushes away eagerly. We have dried up our personalities in a desert of remoteness, and our value to our pupils has diminished in proportion.

To us as well as to the children the new physics offers salvation. It is so flexible that we can prevent its matter from slipping into mere routine. Its subjects of experiment and observation are so numerous that monotony need not be feared. For the youngster it can be made a perpetual adventure, and the teacher can renew his own youth in its ever-extending field. He can keep out of the rut. Let us take courage, then, and explore. Your explorer is your true romanticist, ever young. Let us profit by his example.

WHAT SHOULD A STUDENT GET FROM A BEGINNING COURSE IN CHEMISTRY?[1]

By Wm. McCracken,
Western State Normal School, Kalamazoo, Mich.

Just what particular mental vagary obsessed me when I accepted an invitation to appear on tnis program I do not now recall. Doubtless, however, those of you who are familiar with the history of Kalamazoo, my home town, will have no trouble in tracing it to its habitat in a large and flourishing institution for many years maintained there by the state of Michigan, an institution designated by the title of the Michigan State Hospital for the Insane. As this is my first offense in public among you I will say for the benefit of those who, even now, may be mentally reproaching the framers of this program, that I am no herald of a brighter day in the teaching of chemistry, no voicė crying in the wilderness—"Prepare ye the way of science, make straight in the desert a highway for chemistry." I come before you preaching no gospel of a sure and perfect way of turning out complete chemists in twelve, twenty-four, or thirty-six weeks. My purpose really is to remove from my system as expeditiously as I can some thoughts regarding the teaching of the subject, in which many of us are interested, which to me at least seem more or less germane to it.

We of the present day guild of chemistry teachers no longer need to worry over the question of the admission of chemistry to the curriculum. That was once indeed a burning question, but that particular verbal conflagration has long since been quenched. Chemistry is in and in to stay, regardless of the jeering objections of the humanist and classicist. And having at length admitted chemistry to the hierarchy of approved subjects, the authorities, it must be admitted, did themselves quite proud in the matter of ways and means. There can be no manner of doubt but that chemistry, though one of the youngest twigs on the educational tree, compared with several of the older and more aristocratic branches, is now in more affluent circumstances than are they. Truly the lines of chemistry have fallen in pleasant places. The sinews of war, in the shape of laboratories and equipment, have, on the whole, been bountifully supplied. It is scant wonder that some of the disciples of Vergil and Xenophon look with envy on us chemists as we march gaily down the educational highway right behind the band.

[1]Read before the Physics and Chemistry Section of the Michigan Schoolmasters Club, March, 1917.

So from this standpoint everything looks good—maybe too good. Prosperity is far from a synonym for true success. That was a very pregnant statement made many years ago—"To whom much is given, of him much shall be required." Viewed in this light responsibility begins to loom on our horizon. The real question we teachers have to face is this—are we measuring up to our opportunities, are we really making good?

There is no question but that the years just before us are to be very important from the viewpoint of the teaching of chemistry. The present fearful war, in which we have at last enlisted, has focused the attention of the whole world upon science in general and chemistry in particular. We in this country of boundless material resources have awakened with a gasp of horrified surprise to our extreme lack of chemical preparedness. With untold wealth of raw products we have found ourselves painfully lacking in finished products and in methods and processes of making them. We are in the unhappy position of a man owning a mountain of gold and who is starving to death because he lacks the means of quickly and profitably extracting it. The business world has at length awakened to the idea that back of efficiency in management is the efficiency that furnishes high grade raw materials to supply the machines and which skilfully works out the most favorable way of manipulating them.

Yes, this war has been a real eye-opener to us easy-going Americans, who have complacently thought we were sufficient unto ourselves, for when the show-down came we were anything but ready.

Everyone, now, is thinking of science and its applications, and there is no more fateful word to conjure with than chemistry. Already we have all noticed, I am sure, an increased interest in the subject, an interest which is shown by the large number of young people who are looking forward to chemistry as a profession, a livelihood, a job furnisher, a bread and butter proposition if you will. This demand it seems to me is more likely to increase than decrease as the years go by, and that more and more, in the opinion of the public, the subject of chemistry in the secondary schools is in danger of being classed with stenography and typewriting as a practical subject. Frankly, I am not in sympathy with this view and look upon it with some degree of apprehension. However, in these days when everyone is familiar with the formula H. C. L., the public schools can ill afford to overlook anything that will tend to make the gaining

of bread and butter surer or easier. The very best schools, offering the finest curricula, can in no way offset the danger of a too meager and nonnutritious diet. So it is from no sentimental reason that I object to the teaching of chemistry in the public schools as a practical subject, but because I believe that the actual value of such a course from the bread and butter standpoint is very slight. Doubtless a bright youth could learn in such a course how to identify many substances, how to read accurately a burette showing how many c. c. of permanganate had been used, and from the factor calculate the amount of iron present in a given solution. Doubtless, too, he could get a job, but a job it would always remain for the majority—a job of washing dishes, setting up apparatus, doing a little routine work, a deadly monotonous sort of a job leading nowhere. Of course a bright boy would learn a good deal, especially of manipulation, and would make some progress, but until he dropped everything and obtained a thorough grounding in the fundamentals of the subject, he never could go far. And this is the tragedy of such a practical subject—it may get one a job but seldom leads to a profession.

Our business as teachers of chemistry then is, as I see it, to send our pupils out with a foundation broad and deep enough to permit of the erection of any chemical edifice that may later be attempted, and we shall succeed or fail as we attain to or fall short of this ideal. If we send our pupils out believing they know chemistry when they have acquaintance with a few symbols and atomic weights, or with the ability to rattle off a few equations from memory and glibly recite the main points in the atomic theory, or with the power to test for and identify silver, lead, iron, or cadmium and even to make up n/10 $Na\,O\,H$ and $H_2\,S\,O_4$, we have in fact done them an injury and not at all prepared them for the active struggle of life. We may be proud of our results, but we shall seldom have cause to be proud of our pupils. These things are not chemistry, they are merely some of its facts and applications. They are as far removed from the real science as is the glib recitation of the multiplication table from an understanding of integral calculus.

What we as teachers of chemistry should set before us as the real goal of our endeavor is the successful inoculation of each of our pupils with the potent virus of the "Method of Science." Nothing less than this is worthy of our efforts. With this method in his control the pupil will find himself able to attack a problem

on his own initiative with a success growing ever more and more pronounced as the face of the subject becomes more apparent to him.

Chemistry is, of course, an experimental science, and stands or falls according to the success of its laboratory presentation. The whole course must be built about the laboratory, the recitations and classroom work being merely incidental to the proper appreciation of the experimental work. In the laboratory the pupil handles substances. He examines them, puts them in juxtaposition under given circumstances, and observes what happens. It is imperative that he be wide-awake, absorbed in his work, and closely observant of all that occurs. One of the prime requisites, then, of successful laboratory work is the possession on the part of the observer of a keen and analytical attitude toward his problem. He must be alive, alert with all his senses focused on the operation in hand.

Now, that we fall far short of developing this attitude in our pupils is, I think, self-evident. At least I am willing to admit frankly that I do, and when I talk to my confreres in other departments of scientific work, I find them of the same opinion as myself. They admit that it is the exception to find a student who is keen to observe all that he can, and they confess that the average student seems to be helpless, almost, in the presence of a laboratory problem. Almost in tears they assert that the most of their pupils seem to be absolutely incapable of either seeing, hearing, smelling, tasting, or touching a thing successfully. Haven't you all met with the pupil who insists a precipitate was formed, when as a matter of fact there was no such thing at all? Haven't you all had the experience of having a *close* observer who reports a precipitate but who utterly fails to record its color, glaring though it may be? Haven't you all known the young experimenter who insists he gets hydrogen when he treats copper with hydrochloric acid and who backs up his argument by pointing to the bubbles of gas he sees when he heats his mixture? "In heaven's name," he says, "what can these bubbles be if they are not hydrogen?" Isn't it pretty evident that here right at the start we are forced to admit a failure when we are obliged to confess that there is always a considerable number of our pupils who can never be relied upon to see clearly even a little bit of what goes on under their very noses? The laboratory method is to ask questions of nature and record the answers—in other words to dig up facts. But of what value, pray, are the facts dug up by the mentally blind and deaf? There

never was a time when there was greater need or greater demand for trained observers, and all of us teachers, whether we work in science or not, fail of measuring up to our opportunities if we do not contribute to the filling of this demand. I am satisfied that this is a serious indictment of us as teachers, and I feel sure we do a grave injustice to every student who passes through our hands unquickened. I have no panacea to offer. All I know is that if we teachers of science fail where the whole appeal of our subject is to the physical senses, we have something serious to answer for. As for myself, sometimes, when after a cursory (accent on the first syllable) reading of my students' notes I have imbibed huge draughts of misinformation, I feel that there should be inscribed, not after my pupils' names, but after my own, that ominous word which Daniel translated for Belshazzar—Tekel—"Thou art weighed in the balances (a peculiarly appropriate test for the chemist), and found wanting."

There is more, however, to the method of science than just the mere collection of facts. It is true that without the facts there can be no progress, but facts alone unless they are tabulated and correlated are more apt to be a nuisance than a help. It is not knowledge alone that makes a science or a scientist, but knowledge classified. A ticket seller at a busy window who tries to make change from a box where bills and loose change are hopelessly intermingled does business it is true, but does it very slowly at the risk of frequent error. The person who essays to use a typewriter without becoming familiar with the grouping of the keys does a much more weird job of spelling than the machine usually achieves. The youth who reaches down into a mind full of unclassified knowledge for a fact pertinent to a given case gets something to be sure, but it usually turns out to be a grain of sand rather than a Kohinoor. Now, of course, we do not want fewer facts. Science demands more and more all the time. On the facts are founded the conclusions. The latter are in their very nature always tentative—the only real things are the facts. We are, however, doing a poor job of teaching if we do not by every means in our power strive to make our pupils understand the facts and then help them to a proper classification of them. That the student often fails to note the facts is apparent, that he much more often fails to appreciate their relationships is still more apparent. Here then, also, is a large field for our efforts as teachers.

This important power depends upon a well-developed and

well-controlled scientific imagination. Even those of us who are actively engaged in teaching fail, I think, largely to visualize an experiment. We add this to that with certain results, and that is about as far mentally as the thing goes. And if we have trouble sometimes to "see" things, how much more must our pupils blunder and make mistakes. If one really mentally sees the molecules of a gas moving hither and yon in a confined space, how much clearer becomes the conception of pressure and its relation to both volume and temperature. If one has a mental picture of the molecules of sodium chloride and silver nitrate in equilibrium with their respective ions, how much more exact is his knowledge of what happens when solutions of these two are mixed. If a student has any adequate mental picture of a solution of ammonium hydroxide in equilibrium with its few ammonium and hydroxide ions, I do not see how he can fail to understand the discharge of color in such a solution containing phenolphthalein when ammonium chloride is added. Lacking this picture and recalling that acids discharge the above-mentioned color, he ascribes it to the acid properties of the chloride. If he has any notion at all of volatility he understands why sulphuric acid is used to displace hydrochloric, nitric, and other acids, and is thus enabled to free himself from the fetich that. sulphuric acid does this because it is a "stronger" acid and literally takes hydrochloric acid by the scruff of the neck, as it were, and bodily ejects it.

Alexander Smith says the imagination is a good servant but a poor master—something absolutely essential to the scientist but something which needs a strong curb. In his book on *The Teaching of Chemistry* he has an illuminating paragraph on what one should be able to see in the reaction between manganese dioxide and hydrochloric acid in the making of chlorine. In it he pictures the stubborn manganese dioxide resisting solution, the diluted hydrochloric acid vainly trying to send its scattered molecules to the oxide, the screen of manganous chloride gathering about the oxide and warding off the acid. A mental picture of all these factors is necessary, he asserts, if one is to get any idea of why the process proceeds so slowly.

The following account by Kekule, taken from Alexander Findlay's *Chemistry in the Service of Man*, of how the notion of chain formulas for carbon compounds came to him in London, is worth repeating in this connection. "One fine summer night," he relates, "I was returning by the last omnibus, outside as usual,

through the deserted streets of the metropolis, which are at other times so full of life. I fell into a reverie, and lo! the atoms were gamboling before my eyes! Whenever, hitherto, these diminutive beings had appeared to me, they had always been in motion; but up to that time I had never been able to discern the nature of their motion. Now, however, I saw how, frequently, two smaller atoms united to form a pair; how a larger one embraces two smaller ones; how still larger ones kept hold of three or even four of the smaller; whilst the whole kept whirling in a giddy dance. I saw how the larger ones formed a chain." And then he adds: "I spent part of the night putting on paper at least sketches of these dream forms."

Again he had a dream, this time in Ghent while dozing before the fire. Again he saw the atoms gamboling before his eyes, the chains twining and twisting in snakelike motions. "But look! What was that? One of the snakes had seized hold of his own tail, and the form whirled mockingly before my eyes. As if by a flash of lightning I awoke." Thus out of this dream by the fire was born the clue to one of the most puzzling of molecular structures—namely, that of the benzene ring. From the above then it would appear that one may dream and doze to a very great advantage, provided only his brain has the proper stuff for dreaming and dozing. I fear that we often in our feverish search for facts fail to devote time enough to their digestion and assimilation, the result being that often our work results in aggravated cases of mental indigestion, as a result of which our scientific dreams take on the character of nightmares.

Let us not be disappointed if we do not find many Kekules or Lavoisiers among our students, but let us thank God and take courage if once in a blue moon such a godsend comes our way. So far as we can we should aim to develop in our pupils the ability to form reasonable inferences and logical generalizations. If we are even in a slight degree successful, the universities will welcome our students with open arms and future generations will rise up and call us blessed.

And now with a brief reference to but two more things I will bring this to a close. The work of the scientist is a search after truth—facts are what he seeks. His attitude, then, should be above all things honest and truthful. It is dishonest to guess at results, it is still more dishonest to steal them from others. Anyone who has run a laboratory course knows how difficult it is to bring his pupils to a proper ethical standard as to meum and

tuum in results and apparatus. How incongruous it is to try to make a scientist out of one who is mentally as well as physically dishonest. Moreover, in science the facts are everything, the individual nothing but a means to an end. Hence your true scientist should be and is modest, self-effacing, ever ready to give up a viewpoint if the facts point otherwise. Preconceived notions, unless sustained by facts of later discovery, are the ruination of the scientist. We can do much if we will, and should do all that we can, to instill the modest, truth-loving, and truth-respecting spirit of the real scientist into our pupils. If we do nothing more than this we have yet done a great deal, for the bumptiousness and self-conceit of young America is surely very hard to overcome.

And so, finally, it all comes down to this. We have an interesting subject of vast practical value to the human family; we have good equipment with which to work; we have an interested and sympathetic public; we have plenty of students as bright as those in other branches; we compare, as teachers, favorably with others in training and in zeal. Truly the stars in their courses fight for us, and if we do not get all the results we should, we cannot, I think, avoid taking part of the blame ourselves.

ADOPT THE METRIC SYSTEM.

By H. N. Kauffman,
Kalispell, Montana.

The habits and practices of society are now being weighed in the balance. Many of our wasteful practices must be discarded. Our present system of weights and measures will soon be placed in the defendant's chair and be tried before a jury composed of the "Common Good."

Should the United States adopt the metric system, including the centigrade thermometer, and require that this system be put into general practice?

Why change when we have lived with our present system and have managed to get along? What is wrong with our present system of weights and measures?

Let us first look into the American schoolroom. Here sit the ten million girls and boys prepared to try to digest the food that is furnished them. The first dish is "long measure." Hours are spent in trying to digest inches, feet, yards, rods, fathoms, furlongs, and miles. What is wrong? From step to step there is no relation in the name or the number of units. Hence it is easily forgotten.

The next dish is the "liquid measure." After much difficulty gills, pints, quarts, and gallons are swallowed. Again no relation in the name or number of units is found.

Thus the American boy and girl spend hours choking upon "dry measure," with its pints, quarts, gallons, pecks, and bushels; the "avoirdupois" with its ounces, pounds, hundredweights, and tons; the "apothecaries" with its grains, scruples, drachms, ounces, and pounds; "troy" with its grains, pennyweights, ounces, and pounds; and last that detestable Fahrenheit thermometer. Should we waste time continually on an instrument whose freezing point is not zero, and whose boiling point is not 100°?

In not one of these systems of measure can we find, from step to step, any relation in name or number. Is it any wonder that the average American must carry a handy little notebook along with him in order to refer to the data concerning that particular measure? And then the grief when he leaves that notebook in his other coat!

A crime, yes, a double crime. The youth must waste weeks trying to learn a system that cannot be efficiently used. That time could well be spent upon worth-while cultural and vocational subjects.

Will the metric system save time for the American boy and girl, and can it be used by the average American without the aid of a handy notebook? We can be proud of our monetary system based upon the integers, five and ten. The metric system is more simple, based upon the numeral, ten. As long as a person can remember the numeral ten, he can use the metric system without the aid of a handy pocket notebook. The prefix of the name of each unit designates which ten that it is. All will agree that the metric system is a system easily learned and difficult to forget.

The metric system was formulated in France during the last part of the eighteenth century, and its use is now required by law in practically all civilized nations except the English speaking. Our present system, or lack of system, of measures and weights gradually came into practice from Roman times through the Dark Ages and medieval times up to the eighteenth century. We have followed this crooked medieval path of our ancestors for centuries. But should we continue this wasteful practice?

Today our motto is: "Our utmost for the common good of all." "We affirm that citizenship consists of a sum of duties owed by

each to all." Individual interests cannot supersede the interests of society. Today the best interests of society are the interests of our Government. A close cooperation now exists between our Government and the interests of society. Our Government will soon be asked in the name of the best interests of society that the metric system be required in general practice.

Some grant that the metric system is needed, but that the change would not be practical, or wise. The country cannot adjust itself to this change. The expense would be too great. Business firms would have to reprint their catalogs, records would have to be rewritten, new vessels of measure and scales of weight would have to be manufactured.

True, it will cause some immediate inconvenience to all, and much immediate difficulty to a few. Much of the inconvenience would be ameliorated by placing the date for it to become effective one or two years ahead.

Two million of America's strongest men are returning from France and are acquainted with the metric system. Hence we could not hope for a time at which the people would be better prepared to accept this system.

The general welfare must be placed above the immediate expense and inconvenience of the few. We must build for tomorrow. Following is a note taken from the Washington press:

"Washington, November 24—Adoption of the metric system of weights and measurements for the United States will be urged upon Congress by the American section of the International High Commission, which aims to bring about greater uniformity of commercial law and regulations and more stable financial relations between the United States and the South American republics.

"The American section holds that in view of probable closer commercial relations between North and South America it would be of immense value to business interests to substitute the meter, kilometer, centimeter, liter, hectoliter, hectare, gram, and kilogram for the yard, mile, inch, quart, gallon, acre, ounce, and pound."

This certainly strengthens the contention that the best interests of society demand the change, and that the change is practical and wise. Should not we as members of our respective State Teachers' Associations, instruct our Senators and Representatives that we heartily support this measure and ask that they give it their support when the issue is brought before them?

PROBLEM DEPARTMENT.

Conducted by J. O. Hassler,

Crane Technical High School and Junior College, Chicago.

This department aims to provide problems of varying degrees of difficulty which will interest anyone engaged in the study of mathematics.

All readers are invited to propose problems and solve problems here proposed. Problems and solutions will be credited to their authors. Each solution, or proposed problem, sent to the Editor should have the author's name introducing the problem or solution *as on the following pages.*

The Editor of the department desires to serve its readers by making it interesting and helpful to them. If you have any suggestion to make, mail it to him. Address all communications to J. O. Hassler, 2337 W. 108th Place, Chicago.

SOLUTION OF PROBLEMS.

Correction.

The Editor overlooked an error in the statement of problem 571 which inadvertently crept into the proof. As proposed, it was not the problem suggested by the proposer. As printed in last issue this was corrected. The following is the only solution received of the problem as printed. —*Editor.*

Algebra.

571. *Proposed by Harold M. Lufkin, St. Andrew's School, St. Andrews, Tenn.*

Solve: $2\sqrt{2x+2}+\sqrt{2x+1} = \dfrac{\sqrt{12x+4}}{\sqrt{8x+8}}$.

Solution by R. M. Mathews, Central High School, Duluth, Minn.

Clearing and simplifying the radicals, we have

$$4(x+1)+\sqrt{4x^2+6x+2} = \sqrt{3x+1}$$

whence

$$8(x+1)\sqrt{3x+1} = 12x^2+29x+15$$

and then

$$f(x) = 144x^4+504x^3+753x^2+550x+161 = 0.$$

To locate the roots we apply Sturm's Theorem. The first derived function is

$$f'(x) = 576x^3+1512x^2+1506x+550,$$

and the succeeding Sturm's functions are proportional by positive constants to the expressions:

$$f_1 = -244x^2-443x-217$$
$$f_2 = -20249x-15740$$
$$f_3 = +\text{const.}$$

	f	f'	f_1	f_2	f_3
$+\infty$	+	+	−	−	+
$-\infty$	+	−	−	+	+

Thus no variations are lost, as x varies from negative to positive infinity and accordingly all the roots are complex.

Geometry.

576. *Proposed by G. Ross Robertson, Polytechnic High School and Junior College, Riverside, Cal.*

Construct an equilateral triangle with one vertex on each of three given unequally spaced parallel lines.

I. *Solution by Philomathe, Montreal, Canada.*

Let M_1, M_2, M_3 be the three parallel lines. Take any point P on M_2 and draw the lines PA and PB, each at an angle of 60° to M_2, so that angle APB equals 120°, PA and PB intersecting M_1 and M_3 at A and B, respectively. Describe a circle passing through APB, intersecting M_2 at C. Then ABC is the required triangle, for $\angle ABC = \angle APC = 60°$, and $\angle BAC = \angle BPC = 60°$.

Note. The parallel lines could be replaced by three concurrent lines,

as a more general problem. Also, the equilateral triangle could be replaced by any triangle, knowing its angles.

II. *Solution by Howard R. Park, Riverside (Cal.) High School and Junior College.*

Let XY, MN, PQ be the given lines. Construct several equilateral triangles each of which shall have one vertex at A on XY, a second vertex on MN which we will call B, B′, B″, etc. The third vertex C, C′,C″, etc., will generate some locus.

Choose *any* three of these triangles, ABC, AB′C′, AB″C″. Join CC′ and C′C″.

Triangles ACC′ and ABB′ are congruent. (AC = AB, AC′ = AB′, $\angle$CAC′ = $\angle$BAB′.)

Similarly, triangles C′AC″ and B′AB″ are congruent.

$\angle AB'B'' + \angle AB'B = 180°. \quad \therefore \angle AC'C'' + \angle AC'C = 180°.$

Hence the locus of the third vertex is a straight line. Extend this line until it cuts the third given line PQ in D, and AD is the side of the required triangle.

III. *Solution by Murray J. Leventhal, Stuyvesant High School, New York City.*

Let a, b, c be the parallels. Draw an equilateral triangle a side of which equals AC, the perpendicular distance between a and c. At B erect BD, perpendicular to BC, intersecting b in D; join DC and with C as a center and DC as a radius draw CE to fall within the equilateral triangle. Join DE. By the congruence of triangles BCD and ACE, it is obvious that $\angle$DCE = 60°, therefore, triangle DCE is equiangular and also equilateral.

Solutions were also received from G. I. Hopkins, Daniel Kreth, C. F. W. McCready, A. MacLeod *and other solutions from* Murray J. Leventhal *and* Philomathe.

577. *Proposed by M. Costello, Brentwood, Cal.*

Construct a circle passing through two given points and bisecting a given circle.

Solution by A. MacLeod, Aberdeen, Scotland.

To construct the circle which will pass through the two points A and B and bisect the circle with center C.

Join AC and draw the radius CE perpendicular to AC; join AE and draw EF perpendicular to EA to meet AC produced in F. Draw circle AFB cutting the given circle in P.

Proof: If possible, let PC produced meet given circle in Q and circle AFB in R. Now $AC \cdot CF = CE^2 = CP^2$. Also $AC \cdot CF = CP \cdot CR$.

$\therefore$ CR = CP. $\therefore$ R coincides with Q and circle AFB passes through PQ.

Also solved by Philomathe.

578. *Proposed by Nelson L. Roray, Metuchen, N. J.*

Equilateral triangles are constructed outward upon the sides of any triangle. Prove by elementary geometry only that the given triangle and the equilateral triangle whose vertices are the centroids of the equilateral triangles have the same median point.

I. *Solution by A. MacLeod.*

Given triangle ABC with equilateral triangles BDC, ACE, ABF drawn outward on the sides, and X, Y, Z the centroids of the equilateral triangles.

XYZ is equilateral. (See problem 348, November, 1914.)

Let P, Q, M be the mid points of BC, CE, XZ. From the similar triangles ZAY, BAE, $\angle$AZY = $\angle$ABE. Now $\angle$AZB = 120° and $\angle$XZY = 60°. $\therefore \angle AZY + \angle BZX = 60°$. $\therefore \angle ABE + \angle BZX = 60°$ and $\angle$ABZ = 30°. Hence, if BE meet XZ in K, K is a right angle.

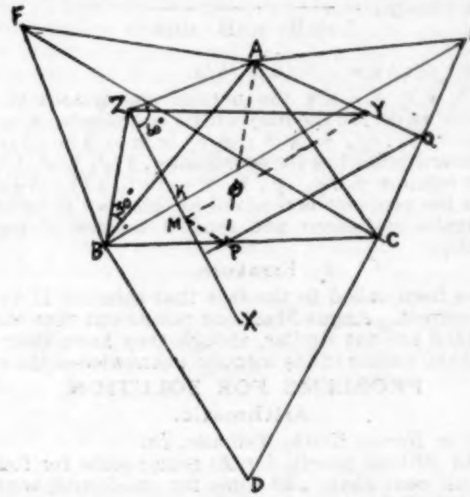
Hence, YM, which is perpendicular to XZ, is parallel to BE. But PQ is parallel to BE. $\therefore$PQ is parallel to MY.

Again, in equilateral triangle XYZ, $2MY = YZ\sqrt{3} = BE = 2PQ$. $\therefore$MY = PQ. Thus MYQP is a parallelogram. $\therefore$AY is parallel to MP and AY = 2MP. Hence, if AP and MY intersect in O, $\triangle$s AOY, POM are similar and AO = 2OP, OY = 2OM. $\therefore$O is the median point of $\triangle$s XYZ, ABC.

II. *Solution by Philomathe, Montreal, Canada.*

The notation has been arranged so that figure for solution I may be used with slight modifications.—*Editor.*

Let ABC be the given triangle and BCD, ACE and ABF the equilateral triangles, having for centroids X, Y, and Z, respectively. Also, let AP, BQ and CR be the medians of ABC, concurrent in O.



We know that AD = BE = CF; now, O and X, dividing AP and DP in the ratio 1 : 3, it follows that OX = AD/3. In the same way, OY = BE/3 and OZ = CF/3. Therefore, OX = OY = OZ and O is the centroid of the triangle XYZ.

579. *Proposed by N. P. Pandya, Amreli, Kathiawad, India.*

Two circles intersect at A and B. The sides DE, FD of a triangle touch both circles. EF intersects AB in C. If AB : AC = EK : EC, where K is the mid point of EF, find the possible positions of EF.

Solution by Philomathe, Montreal, Can.

To construct the side EF, take *any* point E on tangent DE, join AE and draw BL parallel to AE. From M, mid point of DE, draw MN parallel to tangent DF. The intersection of BL and MN is K. Join EK and produce to meet DF at F. EF is the required side, for K is the mid point of EF and from the similar triangles CAE and CBK we have AB : AC = EK : EC.

Remark: E being any point in DE, the problem is indeterminate; but for each position of E there corresponds but one triangle DEF.

Note by Editor: E cannot be chosen at intersection of AB and DE, nor at a point between D and M such that AE is parallel to DF nor at D.

Trigonometry.

580. *Proposed by R. N. Mathews, Riverside, Cal.*

If P is the Brocard point of a triangle such that the angles PAB, PBC, PCA are equal, and p_1, p_2, p_3 its distances to a, b, c, respectively, then $p_1 : p_2 : p_3 = (a+c) : (a+b) : (b+c)$.

Solution by Philomathe.

We have

$$\frac{\mathrm{BP}}{c} = \frac{\sin\alpha}{\sin(\pi-\mathrm{B})} = \frac{\sin\alpha}{\sin\mathrm{B}}. \quad \text{Hence, } \mathrm{BP} = \frac{c\sin\alpha}{\sin\mathrm{B}};$$

Likewise,

$$\mathrm{AP} = \frac{b\sin\alpha}{\sin\mathrm{A}} \text{ and } \mathrm{CP} = \frac{a\sin\alpha}{\sin\mathrm{C}}.$$

Now

$$p_1 = \text{BP}\sin\alpha = \frac{c\sin^2\alpha}{\sin\text{B}},\ p_2 = \frac{a\sin^2\alpha}{\sin\text{C}},\ p_3 = \frac{b\sin^2\alpha}{\sin\text{A}}.$$

Therefore,

$$p_1 : p_2 : p_3 = \frac{c}{\sin\text{B}} : \frac{a}{\sin\text{B}} : \frac{b}{\sin\text{A}}$$

or

$$p_1 : p_2 : p_3 = c/b : a/c : b/a.$$

Remark: c/b, a/c, b/a are the normal coordinates of the Brocard Point; from them we derive the barycentric coordinates x, y, z, as follows:

$$x : y : z = ap_1 : bp_2 : cp_3 = ac/b : ab/c : bc/a = 1/b^2 : 1/c^2 : 1/a^2.$$

The second Brocard point has for coordinates, $1/c^2$, $1/a^2$, $1/b^2$.

Note: Is the relation $p_1 : p_2 : p_3 = (a+c) : (a+b) : (b+c)$ a misprint?

A letter from the proposer is received as this goes to print. He apologizes for the erratic statement and sends a solution giving same results as above.—*Editor.*

Erratum.

Attention has been called to the fact that solution II to problem 558 in June is not correct. Angus MacLeod points out that the two quadrilaterals mentioned are not similar, though they have their angles equal. The Editor and the author of the solution acknowledge the error.

PROBLEMS FOR SOLUTION.

Arithmetic.

591. *Proposed by Daniel Kreth, Wellman, Ia.*

A boy bought 20 lead pencils for 20 cents; some for four cents each, some for one-half cent each, and some for one-fourth cent each. How many did he buy? Solve by arithmetic.

Algebra.

592. *Proposed by Walter R. Warne, Dickinson College, Carlisle, Pa.*

Solve:

$$\frac{9(x+y)^{\frac{1}{2}}}{8y} + \frac{9(x+y)^{\frac{1}{2}}}{8x} = \frac{8}{7}$$

$$\frac{7(x-y)^{\frac{1}{2}}}{4y} - \frac{7(x-y)^{\frac{1}{2}}}{4x} = \frac{1}{9}$$

[Alsop's *Treatise on Algebra* (1857).]

593. *Proposed by Walter R. Warne, Dickinson College, Carlisle, Pa.*

Solve:

$$x^2+xy+y^2 = 37$$
$$x^2+xz+z^2 = 28$$
$$y^2+yz+z^2 = 19$$

[Haddon's *Rudimentary Algebra* (1855).]

Geometry.

594. *Proposed by Harris F. MacNeish, College of the City of New York.*

If on the sides of any triangle there are constructed outward (inward) regular polygons of the same number of sides, the triangle whose vertices are the centers of the three polygons has the same median point as the original triangle.

595. *Proposed by C. E. Githens, Wheeling, W. Va.*

Given the base, difference of the angles at the base, and difference of the remaining sides, to construct the triangle. What condition would make the solution impossible?

IGNITING FLASH POWDER.

An electrical arrangement for igniting flash powder can be made very easily, with materials which are readily procurable. The powder itself is ignited on a block of hard wood, upon which are screwed down two lengths of clock spring. These are in a line, with their adjacent ends about a quarter of an inch or less apart. Under these ends is slipped a bit of the finest iron wire procurable, such wire as is used for binding flowers. The springs are connected up with a push or switch, with the requisite length of flexible wire, and a dry battery such as is used in the pocket torches now to be found everywhere almost. Over the fine wire which connects up the two springs is heaped the flash powder; and on pressing the push, the current heats the fine wire red hot and ignites the powder at once. Instead of the springs, a couple of screws may be driven into the wood and connected up, the wire being wound around one and then carried across to the other; but the springs take less of the fine wire, and a fresh piece is usually but not invariably wanted for each flash. The whole thing can be fixed up in about half an hour. I use a solid block of oak about 4x3x6 inches, as this is heavy enough to stay where it is put, against the drag of the wires; the flashes have charred its surface a little, but have not otherwise affected it. It cannot be protected with metal as this would short-circuit the current.—[*Photo-Era.*

SCIENCE CLUB AT STATE NORMAL SCHOOL FOR WOMEN, EAST RADFORD, VA.

This club was organized three years ago for "The promotion of better science teaching in the rural schools." The members are the laboratory assistants and the seniors in the Science Department. The club meets every two weeks. The programs deal with practical questions of applied science, of vital importance to rural teachers. The following are some of the problems that have been discussed this fall:

November 1. "What can the rural teacher do to improve the sanitary conditions about the school premises?"

I. Conditions usually found.
   1. Water supply.
   2. Sewage.
   3. Waste, etc.

II. How can the pupils be organized to help?
   1. Organization of boys' and girls' committees.
   2. Authority given these committees.
   3. The enlistment of parents.

III. Round table discussion.

December 5. "How can general science best be treated in the rural high school?"

I. The problem method.
   1. Only problems that the teacher is best able to handle.
   2. Problems within the scope of the pupils' environment.

II. Laboratory work.
   1. Simple experiments involving principle rather than technique.
   2. Simple apparatus, preferably homemade.
   3. Home work.
   4. Individual reports to the class.

III. Field work.
   1. Topography of the vicinity.
   2. Plants and animals of the vicinity.

IV. Round table discussion.

Olive Flora Bryson.

SCIENCE QUESTIONS.

Conducted by Franklin T. Jones.

The Warner & Swasey Company, Cleveland, Ohio.

Readers are invited to propose questions for solution—scientific or pedagogical—and to answer questions proposed by others or by themselves. Kindly address all communications to Franklin T. Jones, 10109 *Wilbur Ave., S. E., Cleveland, Ohio.*

Please send examination papers on any subject or from any source to the Editor of this department. *He will reciprocate by sending you such collections of questions as may interest you and be at his disposal.*

State Board Questions.

Please send copies of state questions or teachers' examination questions to the Editor of this department. One such list only has been sent in; namely, by Mr. G. H. Stone.

Acknowledgments.

Lists of questions are acknowledged from Dr. Lyman C. Newell, Boston, Mass., and Mr. A. H. Smith, Riverside, Cal.

Tests in Chemistry.

The Editor of this department has prepared *ten* tests in chemistry. He would like assistance in standardizing them. *Are you willing to cooperate?* Full acknowledgment of assistance will be made. The Editor regards such a venture as no "one man" proposition, but an endeavor which is worthy of considerable effort. To the *first ten* who respond, the Editor will engage to supply duplicate copies without charge for the members of the respective classes. Please let him know at once what you need so that the necessary printing may not be delayed.

A set of chemistry tests, *properly standardized,* should be of great assistance to all teachers. Are you not interested to the extent of helping to standardize some tests?

QUESTIONS AND PROBLEMS FOR SOLUTION.

311. *Proposed by A. H. Smith, Riverside, Cal.*

The "Press" of March 25, 1918, stated that it might be possible to account for the long distance (70 miles?) over which the projectiles from the long range gun were shelling Paris by assuming that one shell was inside another and that successive explosions took place during the flight of the shell. Does this statement agree with the laws of physics?

312. What is the best question on physics you have discovered this year? Send it in. Send in some good war-peace questions on physics.

313. What is the best question on chemistry you have found this year? Send it in, together with any war-peace questions on chemistry.

SOLUTIONS AND ANSWERS.

309. *Proposed by Franklin T. Jones.* (The readers of School Science and Mathmematics have ideas as to *Science in the High School of Tomorrow. Please send in these ideas as soon as you receive this journal.*)

(*a*) What should be the science in the high school of tomorrow?

(*b*) What immediate modifications of our science work should be introduced to meet the present emergency in education?

(*c*) Should these modifications become fixtures?

(*d*) What modifications have you already introduced?

310. What questions on science, new and old, has the war brought to our attention?

Answer by A. Haven Smith, Riverside Junior College, Riverside, Cal.

The questions you propose in the last number of School Science and Mathematics have been in my mind for some time. Of course the war is over, but the questions are still important.

As I looked over my work in physics at the close of last year I found that the greatest difference had been in the applications of the principles rather than a change in matter taught. I omitted almost all of static electricity and spent this time on alternating currents. The subject of

sound was also cut to about two weeks' work. More time was spent on the laws of accelerated motion than in normal years. Our problem here is simpler than in most localities, for we have only boys to deal with. They were mightily interested in the problems dealing with cannon balls. Here are two problems given the class in Junior College Physics at the time of the long range bombardment of Paris last spring.

"If the gun which is supposed to be shelling Paris is 70 miles away, find with what velocity the projectile must leave the gun. How long would it take to reach Paris? What is the highest point it would reach?"

"The 'Press' of last night (March 25) said that it might be possible to account for the long distance over which these balls were apparently traveling by assuming that one shell was inside another and that successive explosions took place during the flight of the shell. Does this statement agree with the laws of physics?"

I hope a number of others will answer the questions asked.

VOCATIONAL EDUCATION ASSOCIATION OF THE MIDDLE WEST.

PRELIMINARY ANNOUNCEMENT PROGRAM.

The program of the fifth annual convention of the Vocational Education Association of the Middle West, which is to be held in Chicago on January 16, 17, and 18, 1919, promises to be one of the best which this association has ever held. Meetings in the past have established a reputation for dealing with timely and pertinent questions confronting the field of vocational education in a vigorous and forceful manner. The valuable discussions which were held last year, with the effects of the war as the dominant note, will long be remembered by those in attendance. Previous meetings, before the passage of the Smith-Hughes act, contributed a great deal towards clarifying methods of procedure in the Middle West. This year, with the dawn of peace, everyone connected with the administration and teaching of vocational work in the schools will be sure of receiving a great deal of profit and stimulation for the serious work which lies immediately ahead.

WAR AND PEACE.

The war is over; peace reigns on earth. But in Europe today there are more than 2,000,000 American soldiers who took an important part in bringing the war to a victorious end, and these men must be fed and clothed for a long while to come. It is estimated by the War Department that the cost of equipping and maintaining an American soldier in Europe is $423.27 a year.

The American army was transported to France at the rate of 250,000 men a month by giving them first call on the shipping facilities of the United States. If they could be brought back to their homes thus speedily—and it is doubtful if they could—it would require at least eight months. It is obvious, therefore, that we must continue to raise money with which to maintain our army abroad.

"We are going to have to finance peace for a while," said Secretary of the Treasury McAdoo, "just as we have had to finance war."

And that means that the American people, having supported four Liberty Loans with a patriotism which future historians will surely extol, are to be vouchsafed an opportunity to support our victorious peace. There will certainly be at least one more Government Loan. There probably will be two more, and possibly three. At any rate, the next Loan must be prepared for and its success made certain. Get ready now to buy more bonds.

ARTICLES IN CURRENT PERIODICALS.

American Botanist, for November; *Joliet, Ill.*; $1.25 *per year*, 35 *cents a copy*: "The Pineapple Guava," Vaughn MacCoughey; "The Purple Water Avens," Lucina H. Lombard; "The First Apple Tree of the Northwest," H. E. Zimmerman; "Germination of Wild Cucumber Seed," J. F. Sempers.

American Journal of Botany, for November; *Brooklyn Botanic Garden, Brooklyn, N. Y.*; $5.00 *per year*, 60 *cents a copy*: "Calcium Oxalate in the Dasheen," O. F. Black; "The Influence of Certain Added Solids upon the Composition and Efficiency of Knop's Nutrient Solution," E. H. Toole and W. E. Tottingham; "Uredinales of Guatemala Based on Collections of E. W. D. Holway. III. Puccinia, Exclusive of Species on Carduaceae," J. C. Arthur; "On the Osmotic Concentration of the Tissue Fluids of Phanerogamic Epiphytes," J. A. Harris.

American Mathematical Monthly, for November; *27 King Street, Oberlin, Ohio*; "Third Summer Meeting of the Mathematical Association of America," W. D. Cairns; "Mathematical Encyclopedic Dictionary," G. A. Miller; "Fundamentals in the Mathematics of Investment," E. L. Dodd; "Problems and Solutions"; "Questions and Discussions: Fifth-Power Problems," C. B. Haldeman; "Undergraduate Mathematics Clubs"; "Collegiate Mathematics for War Service: Some Drawings and Graphical Solutions in Navigation," W. H. Roever.

American Naturalist, for October-November; *Garrison, N. Y.*; $4.00 *per year*, 80 *cents a copy*: "Migration as a Factor in Evolution," Charles C. Adams; "A Study of Hybrids in Egyptian Cotton," Thomas H. Kearney and Wolton G. Wells; "Genetic Relations of the Winged and Wingless Forms to Each Other and to the Sexes in the Aphid Microsiphum Solanifolii," Dr. A. Franklin Shull; "Organic Evolution and the Significance of Some New Evidence Bearing on the Problem," L. B. Walton.

Blast Furnace and Steel Plant, for December; *Pittsburgh, Pa.*; $1.00 *per year*, 15 *cents a copy*: "Steam Turbine Progress and Possibilities Slag Temperature Influence on Refractories," Raymond M. Howe; "Electric Furnace Data for Ferro-Tungsten," Robert M. Kenney; "Waste Heat from Open Hearth Furnaces," Thomas B. Mackenzie.

Botanical Gazette, for November; *University of Chicago Press, Chicago*; $7.00 *per year*, 75 *cents a copy*: "Morphology of Rumex Crispus," Winfield Dudgeon; "Notes on American Trees," C. S. Sargent; "Pine Needles, Their Significance and History," Jean Dufienoy.

Geographical Review, for November; *Broadway at* 156th *Street, New York City*; $5.00 *per year*, 50 *cents a copy*: "An Exploration of the Sierra de Perija, Venezuela (fifteen photos)," Theodoor de Booy; "The Origin and Maintenance of Diversity in Man," Marion I. Newbigin; "Central Hungary: Magyars and Germans (three insert maps in color, one text map, one diagram)," B. C. Wallis; "The Discovery of Yucatan in 1517 by Hernandez de Cordoba (one map)," Marshall H. Saville.

Journal of Forestry, for November; 930 *F. Street N. W., Washington, D. C.*; $3.00 *per year*, 50 *cents a copy*: "Another Word on Site," Filibert Roth; "Height Growth as a Key to Site," E. H. Frothingham; "Nursery Practice in Pennsylvania," George A. Retan; "Knot Zones and Spiral in Adirondack Red Spruce," Edward F. McCarthy and Raymond J. Hoyle; "Some Fundamental Considerations in the Prosecution of Silvicultural Research," Richard H. Boerker.

Journal of Geography, for November; *Appleton, Wis.*; $1.00 *per year*, 15 *cents a copy:* "Political Boundaries in Relation to Wider Political Problems," George G. Chisholm; "In the Land of the Hudson's Bay Company," T. E. Savage; "Points for the Teacher of Mathematical Geography," S. S. Visher; "The Reef-Encircled Islands of the Pacific (Concluded)," W. M. Davis; "Geography Teachers," The Editor; "The Aim of Geography"; "The Sheep and Wool Industry of Queensland"; "Geography: What Facts Shall We Teach?"

Journal of Physical Chemistry, for November; *Ithaca, N. Y.*; $4.00 *per year*; "Methane," William Malisoff and Gustav Egloff; "Crystalloluminescence," Harry B. Weiser.

Marine Engineering, for December; 6 *East Thirty-Ninth Street, New York City*; $2.00 *per year*; "Hog Island, the Greatest Shipyard in the World," W. H. Blood; "Control of the Construction of a 500-Ton Deadweight Fabricated Steel Ship"; "Structural Steel Standardized Cargo Vessels," Henry R. Stuphen; "The Steel Ship and Oxy-Acetylene Welding," J. F. Springer.

Photo-Era, for November; *Boston, Mass.*; $2.00 *per year*, 20 *cents a copy*: "Wedgwood to Talbot (Second of the Professor Pyro Talks)," Michael Gross; "How I Beat the Official Photographer," Herbert W. Gleason; "Modern Lenses and Their Uses," J. A. Dawes; "Our Equine Friend," Grace C. Rutter; "Aerial Fighting Cameras," Wilfred A. French.

Popular Astronomy, for December; *Northfield, Minn.*; $3.50 *per year*, 40 *cents a copy*: "The Illinois Eclipse Expedition to Rock Springs, Wyoming," Jacob Kunz and Joel Stebbins; "The Eclipse at Arlington," J. M. Kemp; "Observations of Total Eclipse of Sun at Limon, Colorado," Morgan Sanders; "Twenty-second Meeting of the American Astronomical Society (Continued)"; "The Influence of Astronomy on Human Thought," Rev. Hector Macpherson.

CAT SKINS, BIRDS, AND DISEASE.

By Horace Gunthorp.

Washburn College, Topeka, Kan.

The writer's attention was recently called to one of the results of the Great War just closed by glancing through the advertisements in the last number of the *American Boy*. On page after page the attention of the boys is called to the fact that all kinds of fur and leather are very scarce and as a result prices on animal skins are extraordinarily high this winter. It would be an interesting problem to make a survey of our small mammals at the present time and again in two or three years, after the present high prices being paid for pelts have returned to normal, in order to ascertain just to what extent the number of some of them is being decreased.

It undoubtedly would be a good thing if the number of certain fur bearers was greatly diminished. For example, we could spare about ninety-eight per cent of our domestic cats, and be a healthier, wealthier, and happier (except for a few misguided individuals) nation. Examining circulars sent out by fur dealers, one finds cat skins quoted at from fifty cents to two dollars each for first-class black ones, while the ordinary cat hide can be sold for from fifteen to twenty-five cents. While most other skins are worth more, owing to their greater scarcity, they are much harder to obtain, and so, time and effort considered, cat skins probably hold out prospects of a more steady and relatively higher remuneration.

Upon inquiry one finds that at the present time there is little effort on the part of the youthful population to reap this profitable harvest running around so near their doors. It seems to the writer that here is a golden opportunity through a small amount of judicious advertising on the part of teachers to start or help a considerable number of their boy pupils along the road to money making, and at the same time rid their community of some of the worst enemies of the birds. Cats not only kill thousands of birds every year, but they are carriers of such diseases as diphtheria, infantile paralysis, influenza, and the like, so a catless city would certainly be a healthier city. It is true that an occasional cat of value (either monetary or sentimental) would be done away with in a crusade against the animals carried on by the boys of a town, but such an individual loss is certainly slight when compared with the great good that could be accomplished for the community as a whole.

BOOKS RECEIVED.

A Study of Birds and Bird Life in the Schools of New Jersey, by G. Leavitt, Normal School, Trenton. 28 pages. 15×23 cm. Paper. 1918. Published by the author.

America and Britain—A Story of the Relations Between Two Peoples, by H. H. Powers. Pages iv+76. 11.5×16.5 cm. Paper. 1918. 40 cents. The Macmillan Company, New York City.

Introduction to Organic Chemistry, by John T. Stoddard, Smith College, Northampton, Mass. Pages xi+423. Cloth. 1918. P. Blakiston's Son & Company, Philadelphia.

Laboratory Manual in Field Crops, by Chester C. Farr, State College of Washington, Everett, Wash. Pages x+63. 13×19 cm. Cloth. 1918. 52 cents. The Macmillan Company, New York City.

Effective Farming, by H. O. Sampson, Normal and Industrial College, Rock Hill, S. C. Pages xxiii+490. Cloth. 1918. $1.32. The Macmillan Company, New York City.

Civic Biology, by Clifton F. Hodge, University of Oregon, Eugene, and Jean Dawson, Dept. of Sanitation, Board of Health, Cleveland, Ohio. Pages x+381. Cloth. 1918. Ginn & Company, Chicago.

The Teaching of Science, by John F. Woodhull, Teachers College, Columbia University. Pages xiv+249. Cloth. 1918. $1.25. The Macmillan Company, New York City.

An Introduction to the Study of Science, by Wayne P. Smith and Edmund G. Jewett. Pages xi+620. 13×19 cm. Cloth. $1.40. The Macmillan Company, New York City.

A Field and Laboratory Guide in Biological Nature Study, by Elliot R. Downing, School of Education, University of Chicago. 118 pages. 15.5×22 cm. Paper. 1918. $1.00. University of Chicago Press.

Pensions for Public School Teachers, by Clyde Furst and I. L. Kendel. Pages xi+85. 18.5×25.5 cm. Paper. 1918. The Carnegie Foundation for the Advancement of Teaching, New York City.

The Geology of Vancouver and Vicinity, by Edward M. J. Burwash. Pages v+106. 17×25 cm. Paper. 1918. $1.50. University of Chicago Press.

Catalog of Physical Apparatus for Educational Institutions. 335 pages. 19.5×27 cm. Paper. 1918. Central Scientific Company, 460 E. Ohio St., Chicago.

SMALL IMPORTS AND LARGE DEMANDS.

The imports of pottery during the year were necessarily small, and the demand was fully equal to the largest domestic supply that would have been produced under normal conditions, but the American potters found it impossible to supply the demand. Though the value of the output was the largest yet recorded, the volume of the product was probably not so large as it had been in some other years. Few plants, if any, ran to capacity, and many of them did not market more than three-fourths of their normal output. The increased cost of labor and raw materials made it necessary to fix higher prices for the wares than those that have prevailed in the last few years. The imports showed an increase over those of 1916 but were much below normal imports before the war. This increase was due chiefly to greater imports from Japan, whose wares are now finding a larger market in the United States.

ERRATUM.

On page 866, December, 1918, issue under "Books Received," sixth paragraph, "Waterbugs" should read "Waterbogs" and $1.75 should be 60 cents.

A NEW SERVICE DEPARTMENT.

The Central Association of Science and Mathematics Teachers is inaugurating a new department—the Service Department. It has always been the aim of the Association to render service to its members through its meetings, its magazine, and its printed *Proceedings*, but it desires to be of even greater service in the realm of science and mathematics to the individual teacher.

Purpose.

The purpose underlying the inauguration of this new department is to give the individual teacher, wherever he may be, assistance in solving his problems. D. A. Lehman of Goshen College, Goshen, Ind., Corresponding Secretary of the Association, is the secretary of this Service Department. All inquiries received by him will be referred for answer to various teachers prominent in their lines of work.

Suggested Lines of Inquiry.

Supplies.—Latest or most efficient apparatus for demonstrating certain problems; special reference books; lists of publications by United States Government; names of reliable supply houses.

Professional Development. Information and advice concerning summer courses, requirements for admission into various school systems (procedure necessary, type of examination, etc.), efficiency measurement cards, vocational guidance.

Problems.—Information upon matters involving reference work in Chicago libraries. Solution of practical classroom problems and teachers' "troubles."

Motto—"The Association Lives to Serve."

Address, D. A. Lehman, Purdue University, La Fayette, Ind.

BOOK REVIEWS.

The Ontario High School Laboratory Manual in Chemistry, by George A. Cornish, B. A., Lecturer in Science, Faculty of Education, Univ. of Toronto, and Chief Instructor in Science, University Schools, Toronto; assisted by Arthur Smith, B. A., Instructor in Chemistry, Central Technical School, Toronto. Authorized by the Minister of Education for Ontario. Pp. 131. 1x13x19 cm. Diagrams. Cloth. 1917. Price 25 cents. The Macmillan Co. of Canada, Ltd., Toronto.

This laboratory manual makes a favorable impression because of its rather original treatment of its subject matter. The order of events is a natural one rather than the stereotyped order of the usual manual. After brief chapters of "General Instructions to the Pupils" and "General Instructions to the Teacher" and a chapter on "Technic," the authors plunge at once into a consideration of "Burning in Air." This is a most fortunate choice of material for arousing the interest of the beginning pupil, who is very much in the state that our race was in at the time that the phlogiston theory of burning began to be questioned. The authors put up to the beginner a series of simple projects or problems stated in beautifully simple language, and put him to work in the laboratory with sufficiently complete and clear directions so that he can find out for himself what the answers to the problems are. The following are some of the earlier projects as stated by the titles of the exercises: "To study what happens when *substances are heated,*" "To find if certain *metals when heated in air change in weight* and to find whether they increase or decrease in weight," "To find if the substances of exercises 2 and 3 are *changed when air is excluded,*" "To find what part of the air phosphorus combines with in burning," etc. It will be seen from the preceding examples that the language in which the project is put to the pupil is such that any child of high school age can at once grasp the idea.

The section on "Burning in Air" is followed by one on "Air and Its Components," then by a brief section on "Some Chemical Laws," in which the pupil is asked "To find if the *total weight* of the substances *changes during a reaction,*" and "To find the *percentage composition of mercury oxide.*" Next comes a chapter on "Water and Hydrogen," one on "Solutions," one on "The Laws of Combination," then "The Shorthand of Chemistry," "Equations, Valency Nomenclature," "Common Salt and Its Derivatives," "Carbon and Its Compounds," "Carbonates in the Household," "Sulphur and Its Compounds," "Oxides, Acids, Bases, Salts," "Compounds of Nitrogen," "The Alkali Metals," and lastly "Bromine and Iodine."

The titles or purposes of the exercises are throughout simple and easily grasped. The directions are clear and neither too brief nor too lengthy. The questions asked are such as must provoke thought. While most of the methods of manipulation are grouped together in the front of the book, it is not the plan of the authors to have the pupils consider these matters until a specific experiment calls for a knowledge of some operation, when the pupil is referred to the chapter on Technic by a paragraph reference. Such references are repeated a few times until it can be assumed that the pupil will not need further instruction on the particular matter.

There is very little in the book that one would criticize adversely. Some might prefer to use the term "concentration" rather than the popular expression "strength" in referring to the amount of a solute in a given amount of solution. Others might doubt the advisability of directing pupils to light mixtures of 2 vols. hydrogen and 1 vol. oxygen in gas

bottles, although if the bottles have thick walls and wide mouths there is probably little danger. These are but passing comments. The manual is an excellent one and does not try to accomplish too much nor anything too difficult for the child of high school age. Given a good teacher to go with it and the pupils who use it should get a fine start in the study of chemistry. F. B. W.

Industrial Arithmetic for Girls, by Nelson L. Roray, Department of Mathematics, Wm. L. Dickinson High School, Jersey City, N. J. Pages viii+196. 13x19 cm. 75 cents. 1917. P. Blakiston's Son & Co., Philadelphia.

For five years the manuscript of this book was used in the Industrial Department of the Dickinson High School, and was prepared in consultation with the teachers of cooking, applied design, and household management. This plan accounts for the large number of excellent applied problems, and for the thorough explanation of the principles upon which they are founded. Among the topics considered are: Cooking, the budget, savings bank accounts, stocks, household accounts, checks, foods, and print shop. There are a large number of exercises for review and drill work in the arithmetical processes, and for the use of the elements of algebra and geometry. H. E. C.

Commercial Algebra, Book II, by George Wentworth, David Eugene Smith, Teachers College, Columbia University, and Wm. S. Schlauch, High School of Commerce, New York. Pages v+250. 14x19 cm. $1.12. 1918. Ginn and Company, Boston.

Book I furnishes a good course in first year algebra for all students, while Book II is prepared especially for advanced classes in commercial high schools. After a brief review with especial attention to powers and roots, the advantage of using logarithms in computations is shown, and a chapter on logarithms and the slide rule prepares the student for computations. Compound interest and its extensive applications in business, equation of payments, annuities, amortization, depreciation, bond valuation and life insurance are the important commercial features presented and treated with a thoroughness that will give the student a real preparation for entering modern business life. There are seven mathematical tables at the close of the book. H. E. C.

Junior High School Mathematics, Book III, by George Wentworth, David Eugene Smith, and Joseph C. Brown, President of the State Normal School, St. Cloud, Minn. Pages vi+282. 13x19 cm. 96 cents. 1918. Ginn and Company, Boston.

In the preparation of this series of books the authors have planned to meet the needs of those students who are to enter college, and to give students who do not expect to enter college an opportunity to understand the elementary notions of algebra, trigonometry, and demonstrative geometry which are the basis of future work in pure mathematics and the tools for practical work in the arts and sciences. Book III consists of three parts: Part I, Algebra; Part II, Trigonometry; Part III, Demonstrative Geometry. It treats algebra in quite a formal way, defines the trigonometrical functions and solves right triangles, using natural functions, and gives some excellent work in angles, parallels, and polygons.
H. E. C.
